December 28, 2016

VIA ELECTRONIC FILING

Ms. Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: FirstLight Hydro Generating Company, FERC Project Nos. 1889 and 2485
Filing of Two Second Year Study Reports

Dear Secretary Bose:

On March 1, 2016, FirstLight Hydro Generating Company (FirstLight) filed 13 reports and two addendums with the Federal Energy Regulatory Commission (FERC or Commission) as part of its licensing of the Turners Falls Hydroelectric Project and Northfield Mountain Pumped Storage Project. Pursuant to the process plan and schedule, FirstLight held its meeting, filed its meeting summary with FERC, and reviewed stakeholder comments. On May 31, 2016, FirstLight filed its response to stakeholder comments. As part of that response FirstLight agreed to conduct a second year of study involving field data collection in 2016 for two studies:

- Study No. 3.3.20 Study to Evaluate Entrainment of Ichthyoplankton at the Northfield Mountain Pumped Storage Project (Second Year Study)
- Study No. 3.3.10 Assess Operational Impacts on Emergence of State-Listed Odonates (Second Year Study)

FirstLight agreed to file the second year study reports by December 31, 2016. Accordingly, both reports are enclosed.

Pursuant to FERC's May 5, 2016 Revised Process Plan and Schedule (Revised Process Plan), FirstLight is required to file reports for four studies (3.3.5, 3.3.19, 3.7.1 and 3.8.1) on March 1, 2017. FirstLight intends to follow the meeting, comment, and response process for the second year study reports for studies 3.3.20 and 3.3.10 pursuant to the schedule established by the Commission in its May 2016 Revised Process Plan. Specifically, pursuant to the Commission's May 2016 Revised Process Plan, FirstLight will hold a study report meeting by March 16, 2017 and file a study report meeting summary by March 31, 2017 for five studies (3.3.20, 3.3.10, 3.3.5, 3.3.19, and 3.8.1). Stakeholders may file disagreements and requests to amend the study plan for these five studies by April 30, 2017, and FirstLight will respond to such disagreements and amendment requests by May 30, 2017.

Study No 3.7.1 pertains to the Phase IA, IB, and Phase II Archaeological surveys. FirstLight filed its Phase IA archaeological survey report in December 2014 and subsequently filed a modified report in May

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2015. In its Phase IA report and in a study report filing dated March 1, 2016, FirstLight stated that it would complete Phase IB and Phase II surveys, if needed, in the event that it is determined that observed erosion is Project-induced, or that there are other potential Project-related effects. On October 14, 2016, FirstLight filed the report for Study No. 3.1.2 Northfield Mountain/Turners Falls Operation Impact on Existing Erosion and Potential Bank Instability (Erosion Causation Study). The Erosion Causation study identified an approximately 1,000-meter stretch of shoreline along the Connecticut River in Massachusetts where erosion is caused in part by Project operation and which the Phase IA archaeological report identified as having high sensitivity for archaeological resources. Accordingly, in November 2016, FirstLight filed an application for a state archaeological permit with the Massachusetts Historical Commission (MHC) in which it set forth its proposed research design and professional qualifications for conducting a Phase IB archaeological survey. FirstLight is currently amending the permit application as requested by MHC. The proposed schedule calls for FirstLight to conduct the Phase IB survey in 2017 when weather and ground conditions permit, after receipt of the state archaeological permit from MHC. On the assumption that FirstLight can complete Phase IB field work in 2017, FirstLight is targeting March 1, 2018 for filing the Phase IB report.

FirstLight is filing this document with FERC electronically. To access the document on FERC's website (http://www.ferc.gov), go to the “eLibrary” link, and enter the docket number, P-1889 or P-2485. FirstLight is also making the document available for download at the following weblink: http://www.northfieldrelicensing.com/Pages/Documents2016.aspx.

In addition to this electronic filing with FERC, a paper copy of the document is available to the public at the Northfield Mountain Visitor Center at 99 Millers Falls Road, Northfield, MA 01360 during regular business hours.

If you have any questions regarding the above, please do not hesitate to contact me. Thank you for your assistance in this matter.

Sincerely,

Gus Bakas

Relicensing Study 3.3.10

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

2014-2016 Study Report

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)

Prepared for:

FirstLight™ Power Resources

Prepared by:

biodrawversity
ecological consulting and communications

GOMEZ AND SULLIVAN ENGINEERS

DECEMBER 2016

EXECUTIVE SUMMARY

FirstLight Hydro Generating Company (FirstLight) is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the Northfield Mountain and Turners Falls Projects using FERC's Integrated Licensing Process (ILP). The current licenses for the Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018.

This report documents the results of Study No. 3.3.10: *Assess Operational Impacts on Emergence of State-Listed Odonates in the Connecticut River*. The study goal was to assess potential effects of Project operations on emerging dragonflies (Insecta: Odonata; hereafter called "odonates") in the Connecticut River. To meet this goal, field surveys were conducted to characterize the habitat, assemblage structure, and emergence and eclosure behavior of odonates in the Project area. This information was compared with existing data on odonates and water surface elevation (WSEL) collected throughout the Project area.

Three phases of fieldwork were completed. Phase 1, completed in 2014, included qualitative surveys of odonate larvae and exuviae at eight sites in the Connecticut River to determine species assemblage structure and to collect habitat data. For tenerals or exuviae, biologists recorded the vertical and lateral distance from the water's edge, and the substrate that each was collected on. Phase 2, completed in 2015, included quantitative odonate surveys, observations of emergence and eclosure behavior, and concurrent collection of WSEL and water temperature data. Surveys for emerging larvae, exuviae, and tenerals were conducted at five sites, with six transects per site, during eight biweekly sampling periods from late May to early September. Biologists looked for larvae exiting the water or crawling on land, and attempted to track and record the time it took for individuals to complete eclosure and fly away. For each exuvia and teneral, the vertical height above the water's surface, the distance from the water's edge, and its eclosure substrate was recorded. Phase 3, completed in 2016, was intended to increase sample sizes for eclosure duration for state-listed odonates and to collect additional data on the vertical heights and horizontal distances traveled prior to eclosure. The speed for all or part of the eclosure process was recorded for 180 specimens, with nearly 90% of these observed in 2016. Surveys for emerging and eclosing larvae were conducted at eight sites in the Turners Falls Impoundment (TFI) and downstream from the Turners Falls Dam, on warm sunny days during peak emergence from late May through mid-July.

A total of 17 species were collected from 2014 to 2016, including the state-listed *Gomphus abbreviatus*, *Gomphus vastus*, *Gomphus ventricosus*, *Neurocordulia yamaskanensis*, and *Stylurus amnicola*. Species found most frequently in the riverine environments in the bypass reach and downstream from Cabot Station in the Connecticut River included *Gomphus vastus*, *Boyeria vinosa*, *Stylurus spiniceps*, *Ophiogomphus rupinsulensis*, *Neurocordulia yamaskanensis*, *Dromogomphus spinosus*, *Gomphus abbreviatus*, and *Macromia illinoiensis*. The lower TFI (Barton Cove) was inhabited by several species more tolerant of lentic conditions, such as *Epitheca princeps*, *Perithemis tenera*, and *Libellula sp*.

For all species combined, larvae crawled a median vertical height of 5.5 ft from the water's surface, and a median distance of 12.5 ft from the water's edge. Among the riverine species, crawl height was greatest for *Macromia illinoiensis*, *Gomphus abbreviatus*, and *Gomphus vastus*; each of these species crawled a median height of near or above 7 ft. Riverine species that crawled the shortest height from the water's surface included *Stylurus amnicola* (median = 2.2 ft), *Stylurus spiniceps* (median = 3.4 ft), and *Ophiogomphus rupinsulensis* (median = 3.5 ft). The more lentic species collected in Barton Cove crawled shorter distances from the water's surface than the riverine species.

Average horizontal crawl distance was usually 10-15 ft for most species, with maximum distances often 3-4 times greater than the average. Shortest crawl distance was for *Perithemis tenera* (a lentic species that prefers to emerge on aquatic vegetation) and *Stylurus amnicola*. Considering crawl height and crawl distance together, the riverine species that tended to eclose closest to the water were *Stylurus amnicola*, *Stylurus spiniceps*, and *Ophiogomphus rupinsulensis*. In general, species eclosed on a wide variety of available substrates.

The time elapsed from when a larva stopped to when it completed metamorphosis ("Start to Free") ranged from 7 to 30 minutes (average= 18 minutes). The time elapsed from completion of metamorphosis to flight ("Free to Flight") ranged from 7 to 96 minutes (average = 39 minutes). Together, these two time periods comprise the critical time period from when a larva stops to eclose to when it flies away ("Start to Flight"). A total of 170 specimens were observed for the entire critical time period. The average duration was 58 minutes and ranged from 24 to 126 minutes.

In terms of understanding potential effects of water level fluctuations, the concern is for those species that tend to remain close to the water's edge, especially in areas of the river where water level fluctuations and rates of change are greatest. For the analysis, Critical Protective Rates (CPR) (ft/hr) were computed for species and species groups, using climbing height quantiles divided by a conservative eclosure duration of 2.0 hrs. CPR values were compared to the 95th percentile of the maximum hourly rates of change (MHR-95%) at several representative sites in the TFI and downstream from Cabot Station, derived from the hydraulic models for the daily period from 4am to 5pm, from May 15 to August 15. The hydraulic model for the TFI was based on data from 2000-2015 (excluding 2010 due to the extended outage at Northfield Mountain), and the hydraulic model for downstream was based on data from 2008-2015 (excluding 2010). For the bypass reach, empirical water level data from 2014-2015 was used. This provided a means of assessing the potential impacts to species or species groups, based on their behavior (climbing height and eclosure time) and the rate of water level changes at locations throughout the Project area.

Water level fluctuations and rates of change may affect odonate emergence in areas of the Connecticut River closest to Cabot Station during the seasonal (May 15-August 15) and daily (4am to 5pm) periods evaluated, which correspond to peak emergence periods for odonates. State-listed odonate species documented in these areas include *Gomphus abbreviatus*, *Gomphus vastus*, *Neurocordulia yamaskanensis*, and *Stylurus amnicola*. Predicted effects were highest for *Stylurus amnicola*; at least 30% of the population, and closer to 50% near Cabot Station, were at risk of inundation based on the MHR-95%. Only a small percentage of the population of *N. yamaskanensis*, *G. vastus*, and the *Gomphus* Group were potentially affected by inundation based on MHR-95%, and these effects were most pronounced close to Cabot Station. Among co-occurring riverine species, *S. spiniceps*, *O. rupinsulensis* and *D. spinosus* were likely most affected by water level fluctuations, based on the tendency of these species to eclose closer to the water.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

cfs	cubic feet per second
CPR	Critical Protective Rate
FERC	Federal Energy Regulatory Commission
FirstLight	FirstLight Hydro Generating Company
ft	Feet
hr	Hour
ILP	Integrated Licensing Process
MADFW	Massachusetts Division of Fisheries and Wildlife
MHR	maximum hourly rate of change
N	number of observations
NHESP	Natural Heritage and Endangered Species Program
Northfield Mountain Project	Northfield Mountain Pumped Storage Project
PAD	Pre-Application Document
PSP	Proposed Study Plan
RSP	Revised Study Plan
RTK-GPS	Real-Time Kinematic-Global Positioning System
SD1	Scoping Document 1
SD2	Scoping Document 2
SPDL	Study Plan Determination Letter
TFI	Turners Falls Impoundment
Turners Falls Project	Turners Falls Hydroelectric Project
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VY	Vermont Yankee Nuclear Power Plant
WSEL	water surface elevation

1 INTRODUCTION

FirstLight Hydro Generating Company (FirstLight), is the current licensee of the Northfield Mountain Pumped Storage Project (FERC No. 2485) and the Turners Falls Hydroelectric Project (FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the two Projects using the FERC's Integrated Licensing Process (ILP). The current licenses for Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018.

As part of the ILP, FERC conducted a public scoping process during which various resource issues were identified. On October 31, 2012, FirstLight filed its Pre-Application Document (PAD) and Notice of Intent with the FERC. The PAD included FirstLight's preliminary list of proposed studies. On December 21, 2012, FERC issued Scoping Document 1 (SD1) and preliminarily identified resource issues and concerns. On January 30 and 31, 2013, FERC held scoping meetings for the two Projects. FERC issued Scoping Document 2 (SD2) on April 15, 2013.

FirstLight filed its Proposed Study Plan (PSP) on April 15, 2013 and, per the Commission regulations, held a PSP meeting at the Northfield Visitors Center on May 14, 2013. Thereafter, FirstLight held ten resource-specific study plan meetings to allow for more detailed discussions on each PSP and on studies not being proposed. On June 28, 2013, FirstLight filed with the Commission an Updated PSP to reflect further changes to the PSP based on comments received at the meetings. On or before July 15, 2013, stakeholders filed written comments on the Updated PSP. FirstLight filed a Revised Study Plan (RSP) on August 14, 2013 with FERC addressing stakeholder comments.

On August 27, 2013 Entergy Corp. announced that the Vermont Yankee Nuclear Power Plant (VY), located on the downstream end of the Vernon Impoundment on the Connecticut River and upstream of the two Projects, will be closing no later than December 29, 2014. With the closure of VY, certain environmental baseline conditions will change during the relicensing study period. On September 13, 2013, FERC issued its first Study Plan Determination Letter (SPDL) in which many of the studies were approved or approved with FERC modification. However, due to the impending closure of VY, FERC did not act on 19 proposed or requested studies pertaining to aquatic resources. The SPDL for these 19 studies was deferred until after FERC held a technical meeting with stakeholders on November 25, 2013 regarding any necessary adjustments to the proposed and requested study designs and/or schedules due to the impending VY closure. FERC issued its second SPDL on the remaining 19 studies on February 21, 2014, approving the RSP for Study No. 3.3.10: *Assess Operational Impacts on Emergence of State-Listed Odonates in the Connecticut River* with certain modifications.

In accordance with the RSP, the study was initially conducted in two phases in 2014-2015. Phase 1, completed in 2014, included qualitative surveys of odonate larvae and exuviae at eight sites from the Connecticut River, including Barton Cove, the Turners Falls Project bypass reach and locations downstream of Cabot Station, to determine species assemblage structure and to collect habitat data. Phase 2, completed in 2015, included quantitative odonate surveys, observations of emergence/eclosure behavior, and concurrent collection of water surface elevation (WSEL) and water temperature data to analyze potential effects of Project operations on odonates and their habitat.

Reports for each work phase were subsequently filed with FERC as part of the ILP schedule. The previous report which contained the results of the 2015 quantitative surveys and included the Phase 1 qualitative results as an appendix, was filed with FERC on March 1, 2016.

This study supplements the work performed in 2014 and 2015, and provides additional information, as requested by the Massachusetts Division of Fisheries and Wildlife (MADFW), The Nature Conservancy

and the Connecticut River Watershed Council in their comments on the Phase 2 report, and based on new data gathered during the 2016 field season.

1.1 Study Goals and Objectives

This study was designed to assess potential effects of Project operations on emerging dragonflies (Insecta: Odonata; hereafter called "odonates") in the Connecticut River. This study had two objectives:

- Synthesis of existing data, supplemented with field surveys, to characterize the assemblage structure and emergence/eclosure behavior of odonates in the Project area.
- Assess the effects of Project operations, especially WSEL changes, on the emergence, eclosure, and habitat of state-listed odonate species and the odonate community.

Three phases of fieldwork were completed. Key elements of Phase 1 are included in this comprehensive report. The Phase 1 work was summarized in an interim report filed with FERC on September 14, 2015, and this report is attached herein as Appendix A. The Phase 2 work was summarized in a report filed with FERC on March 1, 2016. Phase 3, completed in 2016, included additional field data collection on emergence and eclosure behavior, especially for state-listed species or species groups. Phase 3 work supplements the data collected during Phase 2.

FirstLight agreed to collect supplemental emergence and eclosure data for state-listed odonates in consultation with MADFW for Phase 3 work. FirstLight also agreed to perform a modified assessment of the rate of change in WSEL based on stakeholder comments on the initial Phase 2 report.

This document integrates the 2014-2016 data in a single comprehensive report, including a re-analysis of the 2015 odonate data (with addition of 2016 data) and use of hydraulic model output for the effects analysis. This report supersedes the analysis in the Phase 2 report.

1.2 Definitions

Some key terms used in this report are defined below.

Crawl distance	The distance from the edge of the water to the eclosure location, recorded at the time of the observation. It was measured following the contour of the land and assuming movement perpendicular to the river's edge.
Crawl height	The vertical height from the water's surface to the eclosure location, recorded at the time of the observation.
Eclosure	The transformation process of an adult insect from its larval stage.
Emergence	The process of larval odonates crawling out of the water prior to eclosure.
Exuviae	The cast-off exoskeleton of an insect.
Larvae	The aquatic life stage of odonates.
Teneral	The state of an insect immediately after molting. At this time the insect's exoskeleton has not hardened and it may be pale in color.

2 STUDY SITES AND METHODS

2.1 Phase 1: Qualitative Surveys

Agency Coordination and Permitting

A study plan and scientific collection permit application were submitted to the Massachusetts Natural Heritage and Endangered Species Program (NHESP), and NHESP issued the permit on May 15, 2014.

Qualitative Study Sites

FirstLight conducted qualitative surveys of odonate larvae and exuviae at four areas (5 sites) between the Turners Falls Dam and the Route 116 Bridge in Sunderland, and one area (3 sites) in the Turners Falls Impoundment (TFI) near Barton Cove. Appendix A includes the Phase 1 Interim Report, which includes maps and site descriptions.

Qualitative Methods

Surveys were conducted on June 2, 6, 9, and 20 (2014). Barton Cove and the Route 116 Bridge were also checked twice in May 2014 to determine if emergence had begun early. However, the spring of 2014 was cooler than average, river flows were higher than average, and emergence was not detected until early June. Collection methods for larvae included aquatic D-nets and hand picking in the water or on land. Collections were made while wading, snorkeling, and while walking along the riverbank. If present, tenerals or exuviae were collected on the riverbank. For tenerals or exuviae, biologists recorded the vertical height and horizontal distance from the water's edge, and the substrate that each was collected on.

2.2 Phase 2: Quantitative Surveys

Agency Coordination and Permitting

The Phase 2 sampling plan was discussed in a meeting with NHESP and USFWS on April 28, 2015. Concurrence was reached on survey site locations and numbers of transects, and a final sampling plan was sent to NHESP and USFWS on May 12, 2015. A copy of the field sampling plan and associated correspondence is contained in Appendix B. A scientific collection permit was issued by NHESP for the Phase 2 work on June 18, 2015.

Survey Sites

In 2015, FirstLight conducted quantitative surveys at five sites listed below and shown in Figure 2.2-1. Table 2.2-1 lists the surveys dates for each site.

Below Cabot Station

- Site 2015-1: Eastern shore near the Route 116 Bridge (Sunderland)
- Site 2015-2: MADFW conservation lands on the eastern shore upstream from the Sawmill River confluence (Montague)
- Site 2015-3: Area from bike path bridge to Montague City Road, opposite the Deerfield River confluence (Montague)

Bypass Reach

- Site 2015-4: Upstream and downstream from the Rock Dam in the bypass reach (Montague)

Turners Falls Impoundment

- Site 2015-5: Barton Cove (Gill)

Transect Set-up and Data Collection

At each site, FirstLight established six transects that were oriented perpendicular to the river and spanned the continuum from the water's edge into the upland terrestrial vegetation. Transects were established to provide adequate representation of available habitat types, such as natural vegetation, gradually sloping mud/sand, and rock, and of varying bank slopes (i.e., steep versus shallow). Each transect was three meters wide, and extended upslope from the water's edge a minimum of 12 meters (longer in some cases). Transects were monumented with rebar. Benchmark elevations were surveyed and geo-referenced with GPS, and benchmarked to Project (NGVD29) datum using a Real-Time Kinematic-Global Positioning System (RTK-GPS) unit.

The following habitat data were collected for each transect: GPS locations, estimate of bank slope, types and percent cover of each substrate type, substrate embeddedness, presence and percent cover of aquatic and upland plants, and other noteworthy features. All transects were photo-documented (Appendix C). The time of day, weather, water level, and a qualitative assessment of boat traffic were recorded at the time of each survey. Boat traffic was extremely light at all sites on all dates, and no disturbance from boat wakes was ever observed.

Quantitative Surveys

Surveys for emerging larvae, exuviae, and tenerals were conducted at each transect during 8 sampling periods that occurred approximately every two weeks beginning on May 27 and ending on September 2, 2015, with several additional days in June and July to increase sample sizes for eclosure speed (Table 2.2 - 1). Surveys were usually done in the first half of the day, with one site per day on consecutive days. In some cases, two sites per day were surveyed if work proceeded quickly due to low emergence. For each exuvia and teneral, the vertical height above the water's surface, the distance from the water's edge, and its eclosure structure/substrate were recorded. Each exuvia was collected, stored, labeled with site information and date, and identified at the University of Connecticut by Joseph Medwid and his faculty advisor, Dr. David Wagner, with additional assistance from their colleague, Dr. Michael Thomas.

Surveys were generally timed to coincide with fair weather (warm air temperatures, dry and sunny days) and flow conditions that are conducive to emergence (average to below-average flows, based on United States Geological Survey (USGS) streamflow data at the Montague City gage (01170500). Cool rainy weather, and frequent high-flow events from late May to early July made it challenging to schedule fieldwork and may have also delayed or possibly prevented emergence.

Emergence and Eclosure Speed

Biologists looked for larvae exiting the water or crawling on land, and attempted to track single individuals as they crawled upslope and came to rest to begin the eclosure process. The most critical period was the time from when larvae began to eclose to when the teneral's wings hardened and the adult flew away. Biologists used a stopwatch to record the duration of this process. Extremely low rates of emergence and challenging weather conditions during what should have been peak emergence period (late May to early July) greatly reduced our ability to gather these data in 2015.

For each exuvia (i.e., post-eclosure), the vertical height above the water's surface, the distance from the water's edge, and its eclosure structure/substrate was recorded. Crawl height is defined as the vertical height from the water's surface to the eclosure location, recorded at the time of the observation. Crawl distance is defined as the distance from the edge of the water to the eclosure location, recorded at the time of the

observation. It was measured following the contour of the land and assuming movement perpendicular to the river's edge.

2.3 Phase 3: Additional Data Collection on Emergence and Eclosure Behavior

Agency Coordination and Permitting

Based on stakeholder review of Phase 2 results, FirstLight agreed to collect supplemental emergence and eclosure data for state-listed odonates in consultation with MADFW in 2016 (Phase 3). Working with NHESP, FirstLight developed a sampling plan for additional data collection on emergence and eclosure behavior and speed, particularly for state-listed odonate species. Concurrence was reached on potential survey site locations and target replication for each species and species group, and a final sampling plan was sent to NHESP on May 20, 2016. A copy of the field sampling plan and associated correspondence is contained in Appendix D. A scientific collection permit was issued by NHESP for the Phase 3 work in early June.

Survey Sites

FirstLight conducted additional emergence and eclosure surveys in 2016 at eight sites along the Connecticut River, including areas in the TFI, bypass reach, and downstream from Cabot Station. The 2016 survey sites are listed below and shown in Figures 2.3-1 through 2.3-3. Table 2.3-1 lists the surveys dates for each site.

Below Cabot Station

- Site 2016-1: Near the Mt. Holyoke College crew dock (South Hadley)
- Site 2016-2: Western shore upstream and downstream from the Hatfield Boat ramp (Hatfield)
- Site 2016-3: Western shore near the Route 116 Bridge (Sunderland)
- Site 2016-4: Eastern shore near the Route 116 Bridge (Sunderland)
- Site 2016-5: MADFW conservation lands on the eastern shore upstream from the Sawmill River confluence (Montague)
- Site 2016-6: Area from bike path bridge to Montague City Road, opposite the Deerfield River confluence (Montague)

Bypass Reach

- Site 2016-7: Upstream and downstream from the Rock Dam in the bypass reach (Montague)

Turners Falls Impoundment

- Site 2016-8: Mt. Hermon School crew dock, including both the western shore and the eastern shore (Gill and Northfield)

Emergence and Eclosure Speed

As in 2015, biologists looked for larvae exiting the water or crawling on land, and attempted to track single individuals as they crawled upslope and came to rest to begin the eclosure process. The most critical period was the time from when larvae began to eclose to when the teneral's wings hardened and the adult flew away. Biologists used a stopwatch to record the duration of this process. For each exuvia (i.e., post-eclosure), the vertical height above the water's surface, the distance from the water's edge, and its eclosure structure/substrate was recorded. Each exuvia was collected, stored, labeled with the site information and date, and identified to the species level. Surveys were generally timed to coincide with fair weather (warm air temperatures, dry and sunny days) and flow conditions that are conducive to emergence (average to

below-average flows). Surveys were done almost continuously, when weather and flows were suitable, from late May to mid-July. Surveys were usually done in the first half of the day.

2.4 Water Level Fluctuation Impact Assessment

Water Level Data

FERCs February 21, 2014 Study Plan Determination Letter recommended that FirstLight deploy a water level and temperature logger at each quantitative survey reach to record water levels, standardize field measurements, and describe temperature in relation to odonate emergence behavior. Temporary loggers were installed at each site for the duration of the 2015 quantitative surveys to supplement data from the permanent gages at the Turners Falls Dam and the USGS Montague City gage.

For the water level fluctuation impact assessment, FirstLight utilized data from hydraulic models developed for the TFI and the Connecticut River from Montague USGS Gage downstream to Holyoke Dam as part of Study No. 3.2.2. The hydraulic model for the TFI was based on data from 2000-2015 (excluding 2010), and the hydraulic model for downstream was based on data from 2008-2015 (excluding 2010). A shorter period of time was analyzed for the downstream model due to Holyoke Dam experiencing a change in operations in 2008. Data from the year 2010 were excluded because the Northfield Mountain Project was off-line during this period. For the bypass reach, empirical water level data from 2014-2015 at sites above and below Rock Dam were used because an unsteady state (time-varying) model was not developed for the bypass reach.

Data derived from the hydraulic models included hourly WSEL for the daily period from 4am to 5pm, from May 15 to August 15 to correspond with odonate emergence periods, based on recommendation of NHESP. For each hour within the target period, change in WSEL was computed and only the positive rate of change values were included in the analysis. The maximum positive hourly rate of change was determined for each day, then the mean, standard deviation, minimum, 25th percentile, median, 75th and 95th percentile were calculated for each location. The maximum was not used in the analysis in order to eliminate any outliers due to natural flow changes due to precipitation (e.g., Hurricane Irene) or other anomalous conditions.

Hydraulic model data were obtained from representative sites in the TFI and downstream from Cabot Station. Seven locations were assessed in the TFI between Barton Cove and Pauchaug Brook (see Figure 2.3-1), and five locations were assessed downstream of Cabot Station to Route 116 Bridge in Sunderland, MA (see Figure 2.3-2). The transects were chosen to describe water level changes at representative locations throughout the Project area.

Effects of Project Operations on Emergence and Eclosure

Critical height percentiles were computed for each state-listed odonate species (for which there were data), species groups, and co-occurring species. The percentiles represent the critical height at which a given percent of species will not have climbed to. The 5, 10, 20, 30, and 50th percentiles were computed, and these represent critical heights protective of 95, 90, 80, 70, and 50% of individuals within a species or species group. Critical Protective Rates (CPR) (ft/hr) were then computed for species and species groups, using the critical height percentiles divided by a conservative eclosure duration of 2.0 hrs.

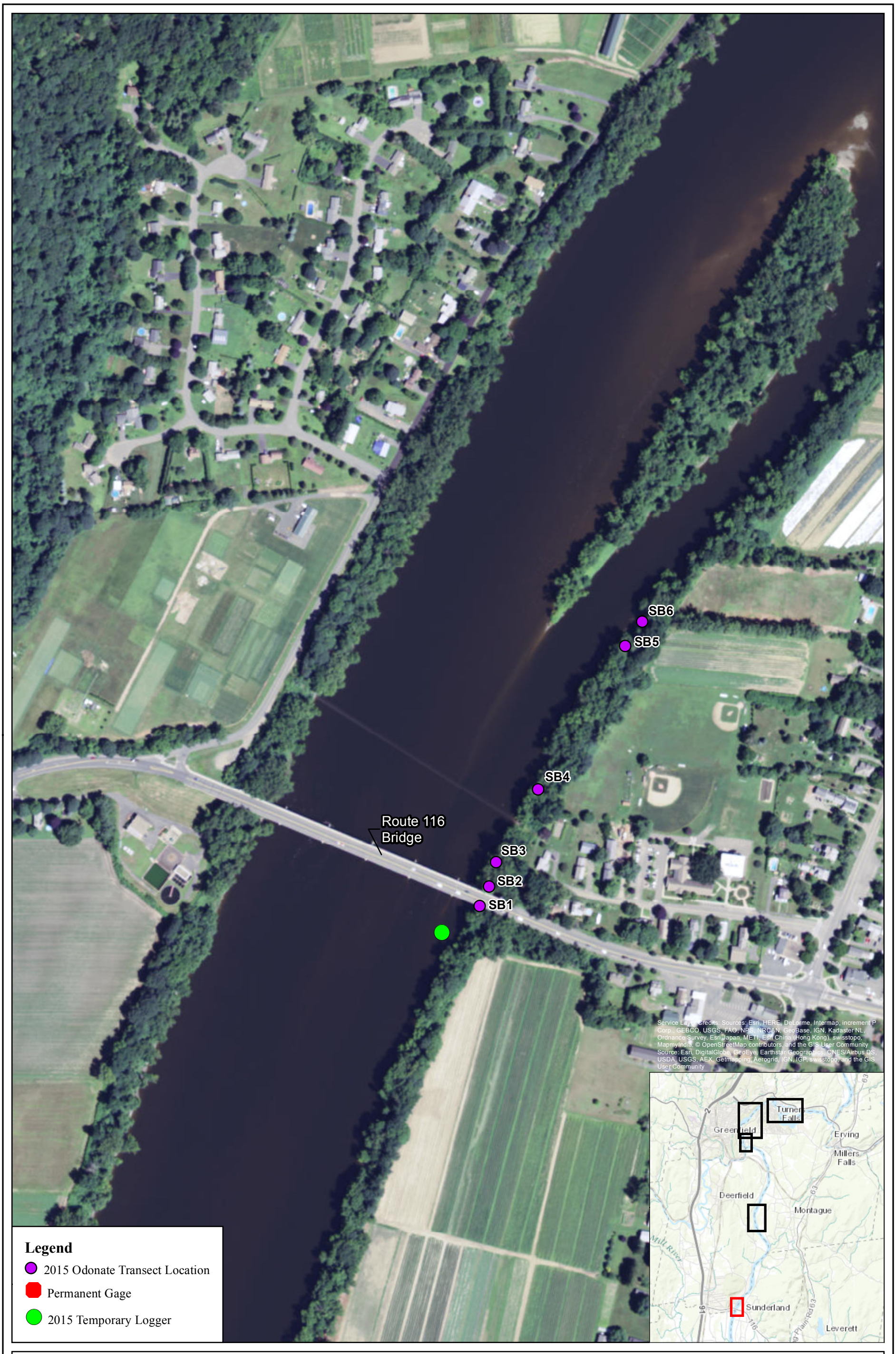
CPR values were compared to the 95th percentile of the maximum hourly rates of change (MHR-95%) (ft/hr) at multiple representative sites in the TFI and downstream from the TF Dam based on WSEL data for the daily period from 4am to 5pm, from May 15 to August 15. This provided a means of assessing the potential effects to species or species groups, based on their behavior (climbing height and eclosure time) and the rate of water level changes at locations throughout the Project area.

Table 2.2-1: Survey Sites and Dates for the Phase 2 Quantitative Odonate Surveys in the Connecticut River.

Site	Location	Town	Date Surveyed (2015)
2015-1	Route 116	Sunderland	May 30. June 10, 20, 25, 30. July 7, 18, 21. August 5, 20. Sept 1.
2015-2	MADFW conservation lands upstream from the Sawmill River confluence	Montague	May 30. June 11, 23. July 6, 14, 21. August 4, 20. Sept 1.
2015-3	Poplar Street boating access area across from Deerfield River confluence	Montague	May 29. June 12, 22. July 9, 17, 20. August 3, 19, 31
2015-4	Rock Dam in the bypass reach; 2 transects upstream and 4 downstream from the Rock Dam	Montague	May 29. June 11, 22. July 9, 17, 20, August 3, 19, 31.
2015-5	Barton Cove	Gill	May 27. June 8, 19. July 2, 8, 25. August 5, 18. Sept 2.

Table 2.3-1: Survey Sites and Dates for the Phase 3 (2016) Odonate Surveys in the Connecticut River.

Site	Location	Town	Date Surveyed (2016)
2016-1	Mt. Holyoke College Crew Docks (below Cabot Station)	South Hadley	June 11
2016-2	Hatfield Boat Ramp (below Cabot Station)	Hatfield	May 31, June 3, June 14, June 17, July 7
2016-3	Route 116 Bridge, West Side (below Cabot Station)	South Deerfield	May 27, June 2, June 4, June 7, June 13, June 17, June 20, June 24, July 5, July 6
2016-4	Route 116 Bridge, East Side (below Cabot Station)	Sunderland	June 4, June 7, June 20, June 22, June 24, June 27, July 7, July 13
2016-5	MADFW Conservation Lands (below Cabot Station)	Montague	May 27, May 31, June 6, June 13, June 22
2016-6	Poplar Street (below Cabot Station)	Montague	July 6
2016-7	Rock Dam (Bypass Reach)	Montague	June 6, June 9, June 14, June 24, July 6
2016-8	Mt. Hermon School (TFI)	Gill	June 4, June 9



FirstLight Power Resources

N

FIRSTLIGHT HYDRO GENERATING COMPANY

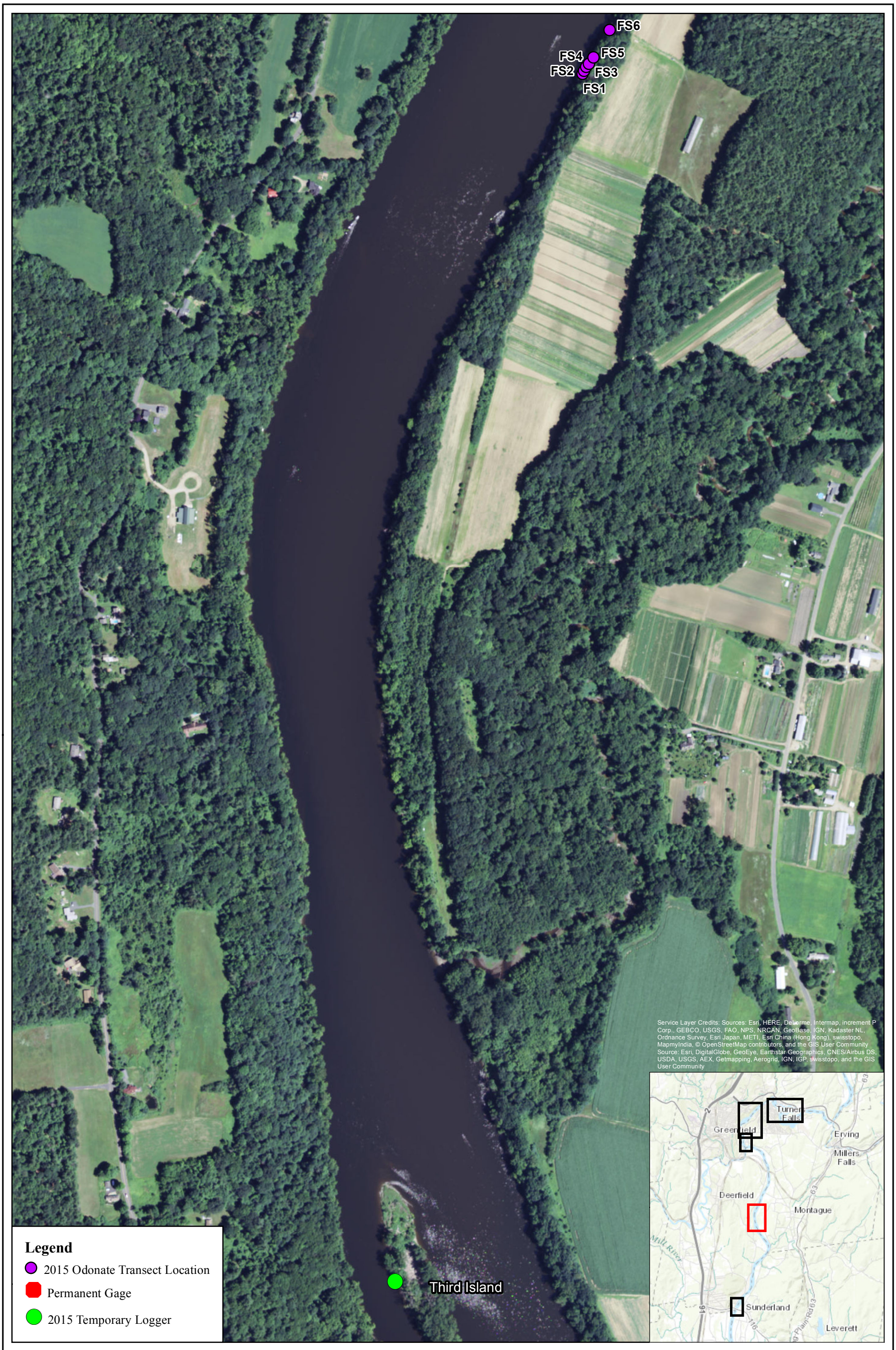
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889
Relicensing Study 3.3.10
Assess Operational Impacts on Emergence of State-Listed Odonates in the Connecticut River

0 150 300 600 Feet

Figure 2.2-1: Phase 2 Quantitative Odonate Survey Sites (2015)

Site 1: Eastern shore near the Route 116 Bridge (Sunderland)

Path: W:\gis\studies\3_3_10\maps\figure_2_2-1 2016.mxd



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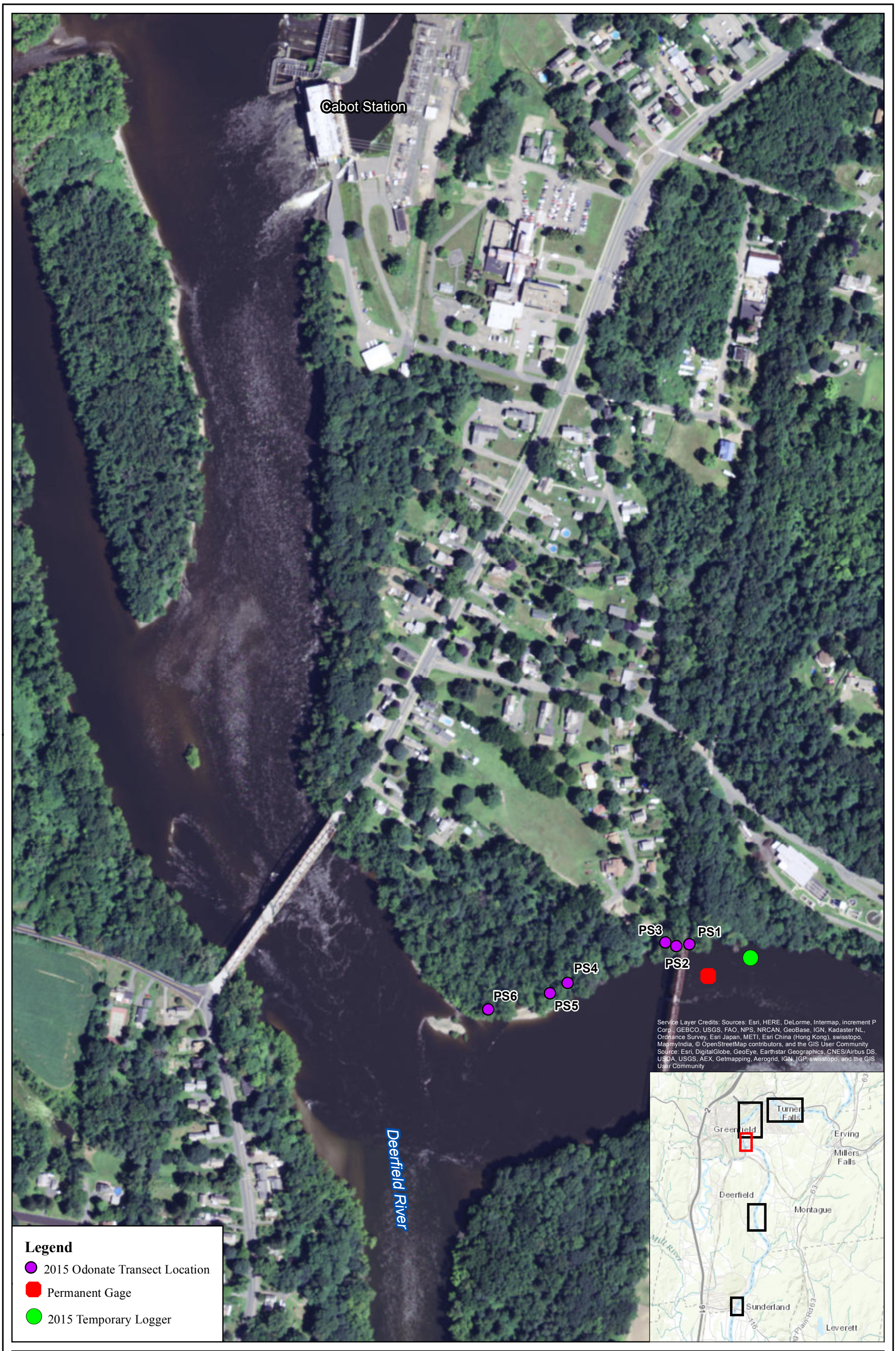
Turners Falls Hydroelectric Project No. 1889
Relicensing Study 3.3.10
Assess Operational Impacts on Emergence of State-Listed Odonates in the Connecticut River

0 225 450 900 Feet

Figure 2.2-1: Phase 2 Quantitative Odonate Survey Sites (2015)

Site 2: Massachusetts Division of Fisheries and Wildlife conservation lands on the eastern shore upstream from the Sawmill River confluence (Montague)

Path: W:\gis\studies\3_3_10\maps\figure_2_2-1 2016.mxd



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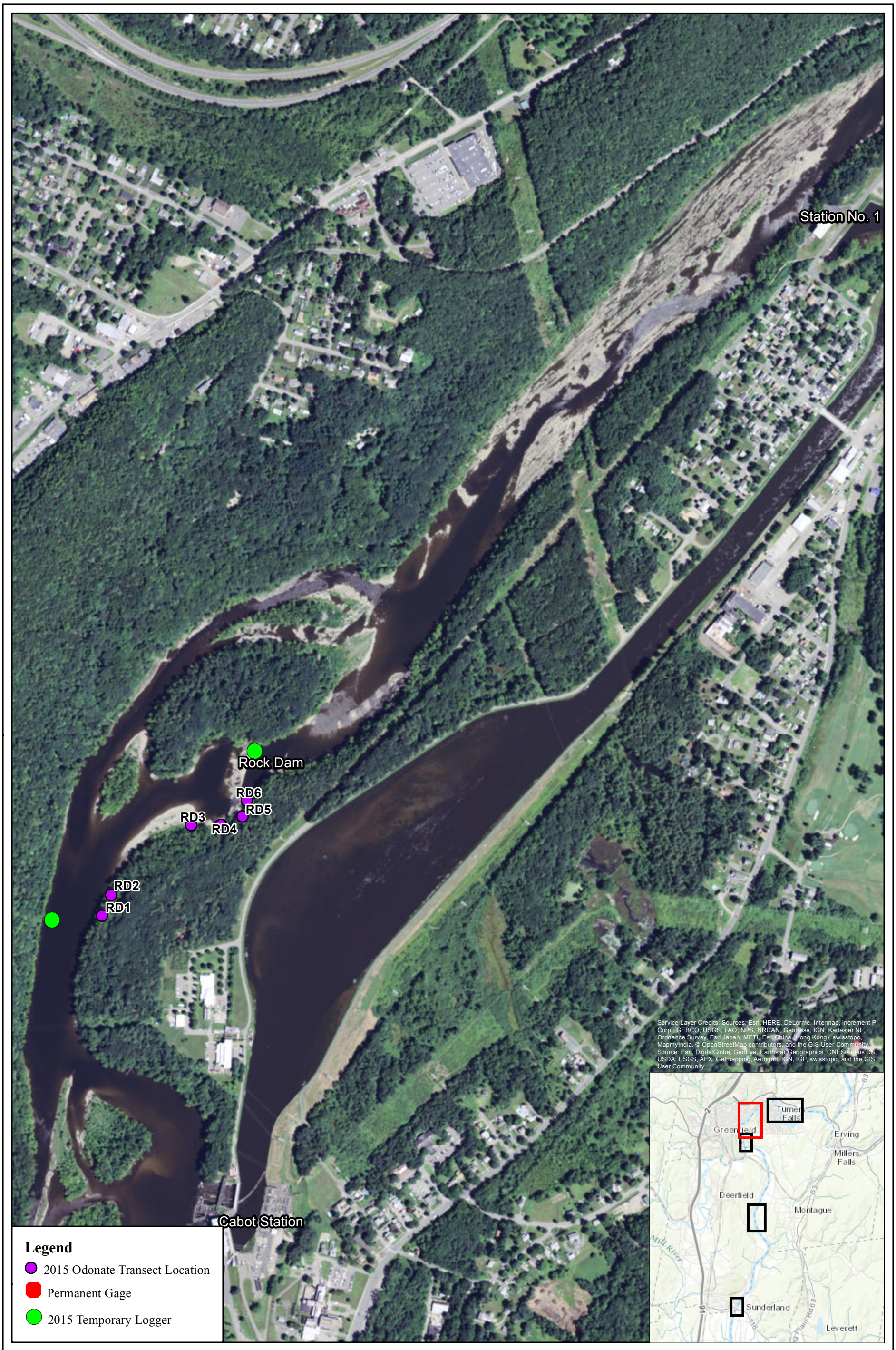
Turners Falls Hydroelectric Project No. 1889
Relicensing Study 3.3.10
Assess Operational Impacts on Emergence of State-Listed Odonates in the Connecticut River

0 150 300 600 Feet

Figure 2.2-1: Phase 2 Quantitative Odonate Survey Sites (2015)

Site 3: Area from bike path bridge to Montague City Road, opposite the Deerfield River confluence (Montague)

Path: W:\gis\studies\3_3_10\maps\figure_2_2-1 2016.mxd



FirstLight Power Resources

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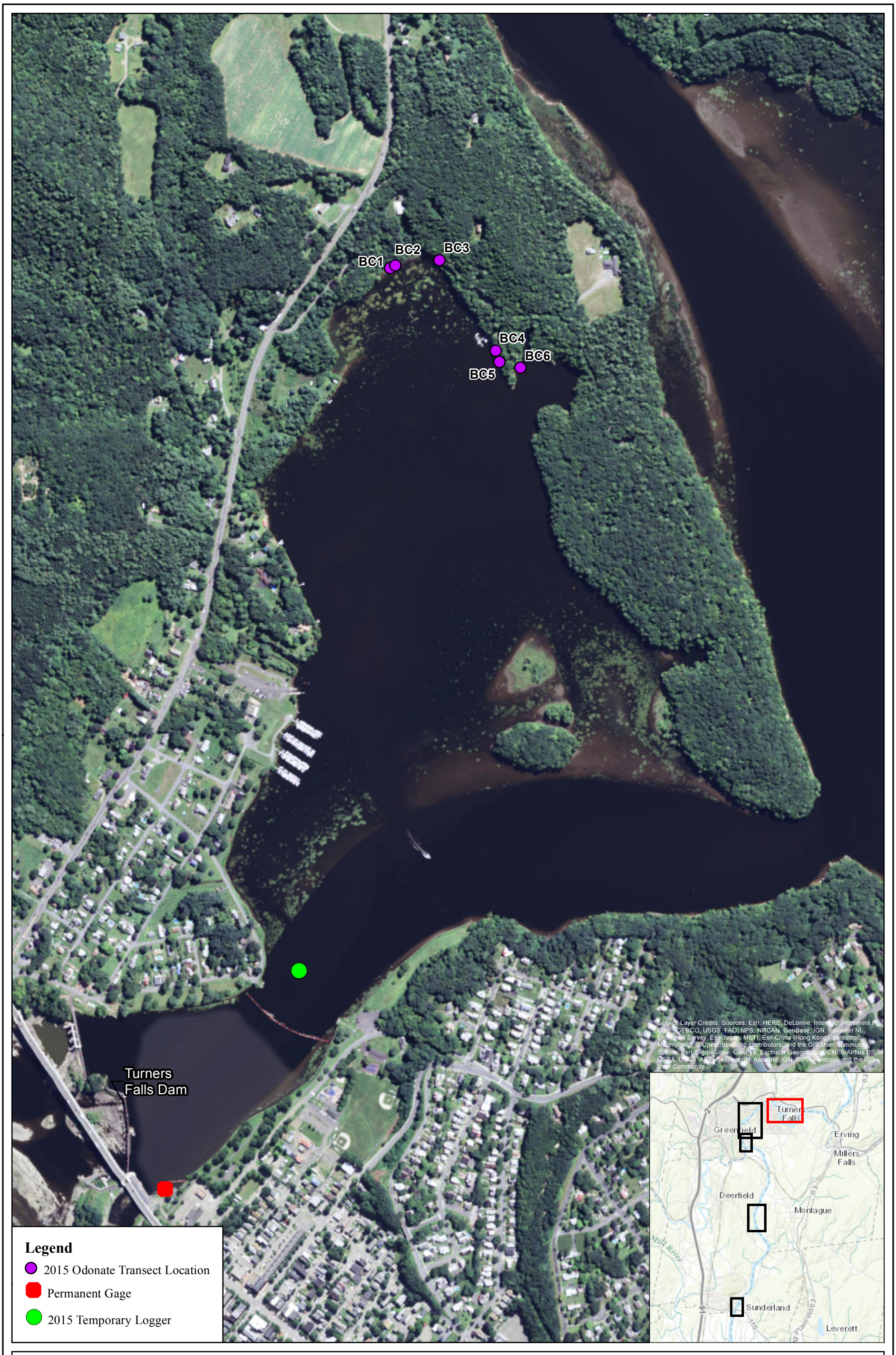
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889
Relicensing Study 3.3.10
Assess Operational Impacts on Emergence of State-Listed Odonates in the Connecticut River

0 300 600 1,200 Feet

Figure 2.2-1: Phase 2 Quantitative Odonate Survey Sites (2015)

Site 4: Upstream and downstream from the Rock Dam in the bypass reach (Montague)

Path: W:\gis\studies\3_3_10\maps\figure_2_2-1 2016.mxd



FIRSTLIGHT HYDRO GENERATING COMPANY

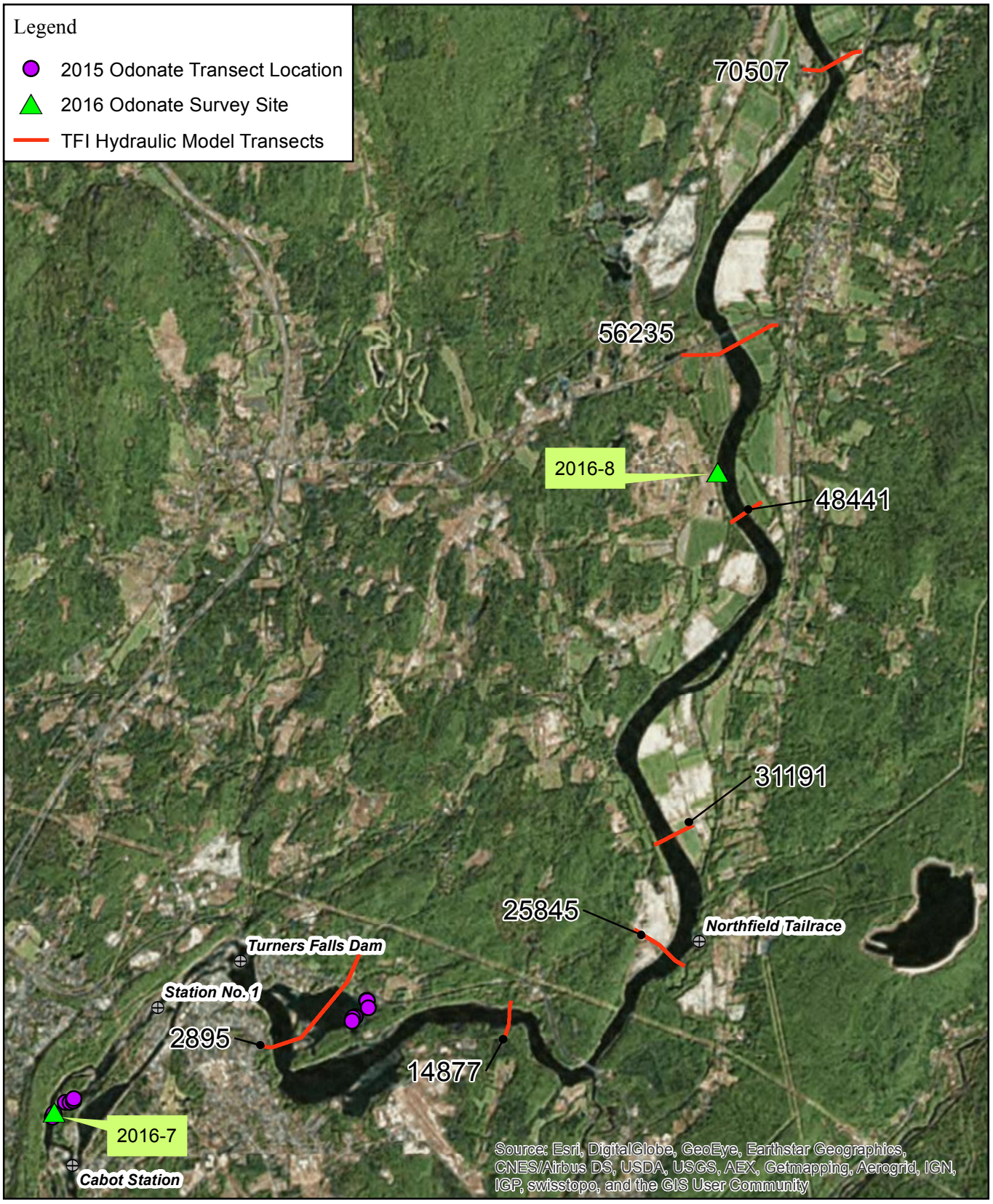
Northfield Mountain Pumped Storage Project No. 2485
Turners Falls Hydroelectric Project No. 1889
Relicensing Study 3.3.10
Assess Operational Impacts on Emergence of State-Listed Odonates in the Connecticut River

0 300 600 1,200 Feet

Figure 2.2-1: Phase 2 Quantitative Odonate Survey Sites (2015)

Site 5: Barton Cove (Gill)

Path: W:\gis\studies\3_3_10\maps\figure_2_2-1 2016.mxd



Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

FirstLight Power Resources

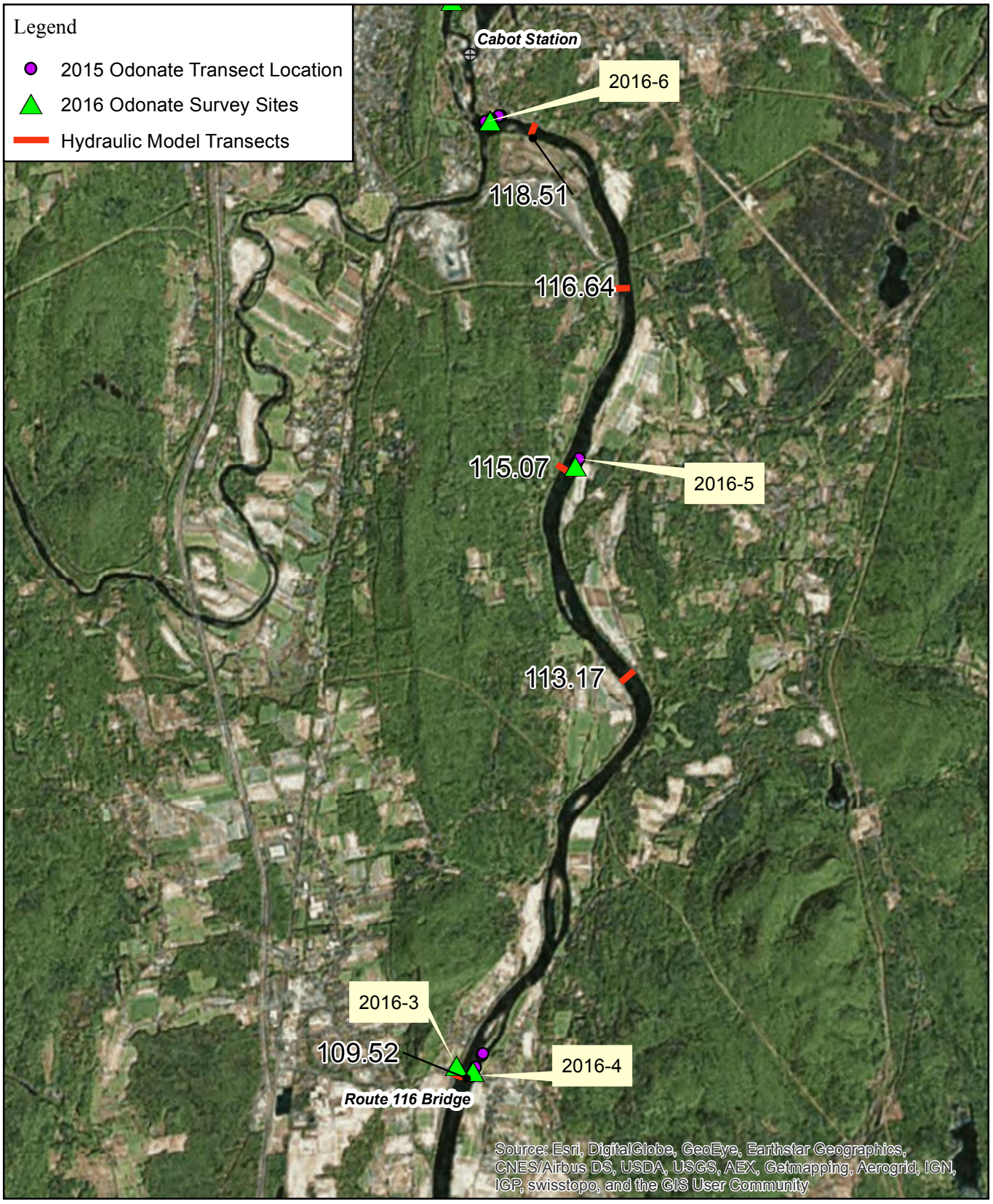
N

RELICENSING STUDY 3.3.10

0 0.5 1 2 Miles

Figure 2.3-1:
2016 Odonate Survey Sites
and Representative Hydraulic Transects;
TFI and Bypass Reach

Path: W:\gis\studies\3_3_10\maps\2016 Odonates Sites US.mxd



Northfield Mountain Pumped Storage Project (No. 2485)
and Turners Falls Hydroelectric Project (No. 1889)

FirstLight Power Resources

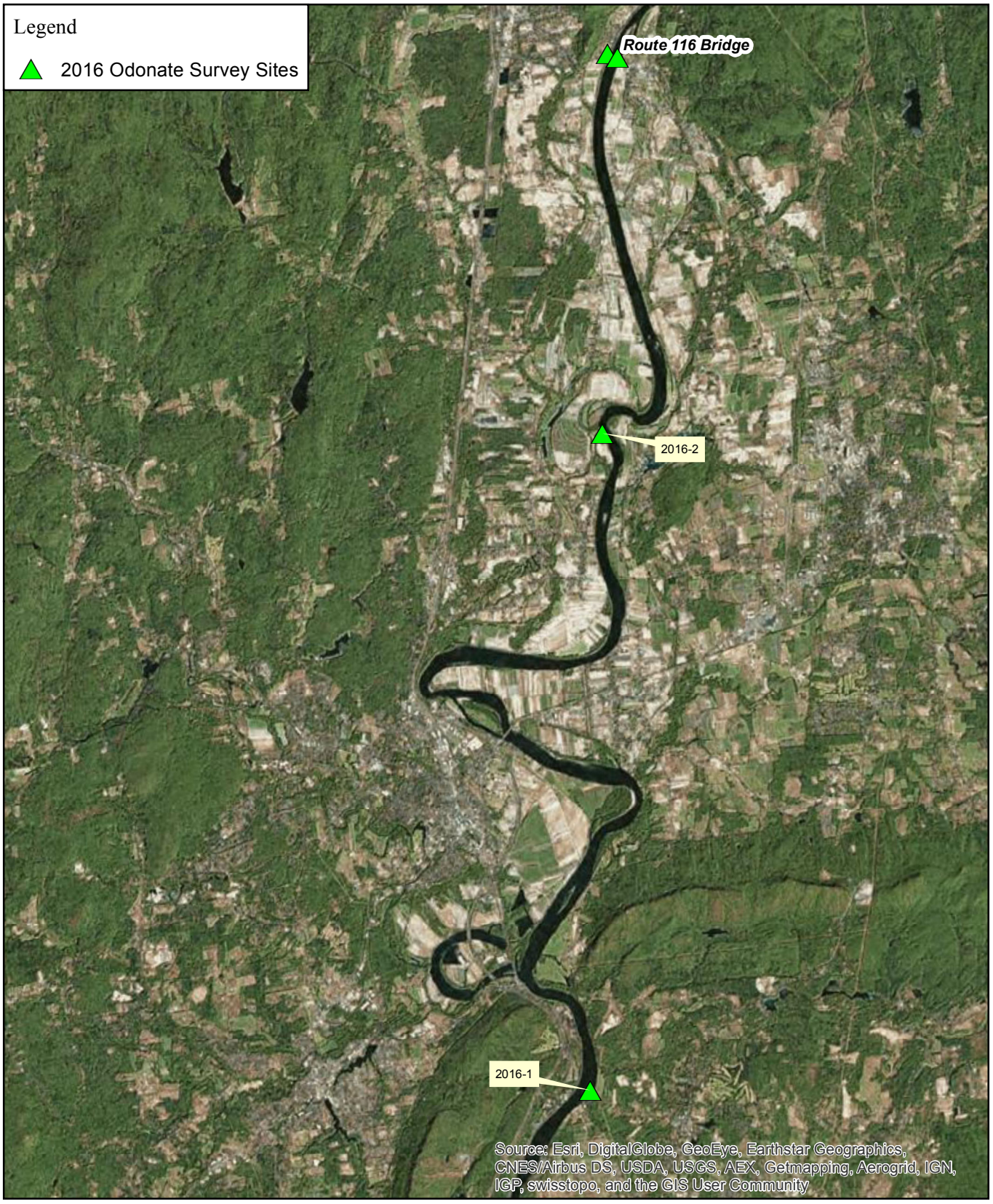
N

RELICENSING STUDY 3.3.10

0 0.5 1 2 Miles

Figure 2.3-2:
2016 Odonate Survey Sites
and Representative Hydraulic Transects;
Downstream of Cabot Station

Path: W:\gis\studies\3_3_10\maps\2016 Odonates Sites DS.mxd



Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)

FirstLight Power Resources

N

RELICENSING STUDY 3.3.10

0 0.75 1.5 3 Miles

Figure 2.3-3:
2016 Odonate Survey Sites
Downstream of Route 116 Bridge

Path: W:\gis\studies\3_3_10\maps\2016 Odonates Sites DS2.mxd

3 RESULTS

3.1 Species Assemblage

In 2014, approximately 250 exuviae were collected across the eight survey sites. A total of 622 individuals representing 16 species were collected during the 2015 season. In 2016, 156 individuals representing four species were observed during eclosure and collected. The genera and species collected from 2014 to 2016 are listed in Table 3.1-1.

Barton Cove

Epitheca princeps, a species common in lentic habitats, was the most common species collected in Barton Cove. The Barton Cove survey sites contain mostly lentic habitat with submerged and emergent vegetation. Other species that can tolerate this type of environment (e.g., *Perithemis tenera* and *Libellula* sp.) were found in Barton Cove, but not found at any of the survey sites in the bypass reach or downstream from Cabot Station.

Bypass Reach and Downstream from Cabot Station

Sites in the bypass reach and downstream from Cabot Station were generally more lotic. Species found most frequently in these areas included *Gomphus vastus* (~55% of total), *Stylurus spiniceps* (~13% of total), and *Boyeria vinosa* (~12% of total). Less common taxa include *Ophiogomphus rupinsulensis, Neurocordulia yamaskanensis, Gomphus abbreviatus*, and *Dromogomphus spinosus*. Rare taxa included *Macromia illinoiensis, Gomphus ventricosus, Stylurus amnicola, Hagenius brevistylus*, and *Basiaeschna janata*.

3.2 Timing of Emergence

In 2015, emergence was first detected early in the fourth week of May, which prompted quantitative sampling to begin on May 26. Summary statistics for exuvia and teneral counts (all species combined) and species richness for each survey site and sampling period are provided in Table 3.2-1, and individual species counts are provided in Table 3.2-2 (also see Appendix E for further breakdown by transect). Counts were low for all species during the first round of sampling, reached a peak during the second round, then dropped and remained consistent for the next four rounds before diminishing to very low numbers during the final two rounds (Figure 3.2-1). Total counts of exuviae and tenerals per transect (all 2015 sampling periods combined) are plotted on Figure 3.2-2.

In 2016, surveys were targeting state-listed species and focused on the time period from late May to mid-July to cover the emergence periods for all *Gomphus* sp., *N. yamaskanensis*, and *S. amnicola*. Sites were checked starting in mid-May to determine the onset of emergence (Table 3.2-3); emergence was detected in the last week of May and peaked in early June at sites downstream from the dam, but despite fair weather, was spotty throughout the survey period. At the site that was checked in the TFI (2 different days), emergence was very sparse and there were few exuviae.

3.3 Crawl Distances and Heights

This analysis focuses on 2015 and 2016 data, which included species-level identification of exuviae. In 2015, crawl distance and height data were collected for 622 individuals and 16 species, with sample sizes per species ranging from 1 to 219. In 2016, crawl distance and height data were collected for 156 individuals and four species. Crawl height is the vertical height from the water's surface to the eclosure location and crawl distance is the horizontal distance from the edge of the water to the eclosure location, both recorded at the time of the observation.

There was little difference in median crawl heights in 2015 and 2016, but median crawl distances were higher in 2016 (Table 3.3-1). For this analysis, the 2015 and 2016 crawl distance and height data are combined, which served to increase sample sizes for the four species that were observed in 2016 (*G. vastus, D. spinosus, S. amnicola*, and *S. spiniceps*). For all species combined, larvae crawled a median distance of 12.5 ft from the edge of the water and a median vertical height of 5.5 ft. (Individual observations for 2015 and 2016 are included in Appendix F.) There was considerable variation within and among species, as shown in Table 3.3-2.

Critical height percentiles, which represent heights protective of a given percentage of individuals within a species or species group, are shown in Table 3.3-2. The more lentic species collected in Barton Cove (i.e., *Perithemis tenera*, *Libellula* sp., *Epitheca princeps*), which tend to emerge on aquatic vegetation, crawled shorter vertical heights from the water's surface than the riverine species that were more prevalent in the bypass each and downstream from Cabot Station. Among the riverine species, crawl height was greatest for *Macromia illinoiensis*, *Gomphus abbreviatus*, and *Gomphus vastus*; each of these species crawled a median vertical height of near or above 7 ft. Riverine species that crawled the shortest median vertical height from the water's surface included *Stylurus amnicola* (2.2 ft), *Stylurus spiniceps* (3.4 ft), and *Ophiogomphus rupinsulensis* (3.5 ft).

Of the species that had a sample size of ≥ 10 individuals, *Boyeria vinosa* crawled the longest distances from the edge of the water, with a median of 16.2 ft, and one individual had crawled 58.9 ft before stopping to eclose. Average crawl distance was usually between 10 and 15 ft for most species, with maximum distances often 3-4 times greater than the average. Shortest crawl distance was for *Perithemis tenera* (a lentic species that prefers to emerge on aquatic vegetation) and *Stylurus amnicola*. Considering crawl height and crawl distance together, the riverine species that tended to eclose closest to the water were *Stylurus amnicola* and *Ophiogomphus rupinsulensis*.

3.4 Substrate Selection

Table 3.4-1 summarizes eclosure substrate preferences based on the 2015 and 2016 quantitative data. Preferences are expressed as a percentage. In several cases, multiple substrate types were recorded for single exuviae (e.g., on detritus, among rocks). Percent preference was computed by dividing the number of observations for each substrate type per species by the total number of substrate observations for each species. In general, species eclosed on a wide variety of available surfaces. In Barton Cove, this included large amounts of emergent aquatic vegetation, detritus, rock, trees, and roots. In the bypass reach and downstream from Cabot Station, emergent aquatic vegetation was mostly absent and species eclosed on bare sediment (from silt to coarse rock); ground-level cover such as moss, roots, and detritus; and on vertical surfaces such as stems of herbaceous plants, vines, trees, and vertical rock faces. Table 3.4-2 provides a habitat summary for each site that was quantitatively sampled in 2015.

3.5 Emergence and Eclosure Speed

With the 2015 and 2016 data combined, a total of 180 individuals, representing eight taxa, were observed during part or all of the emergence process. This included observations of three state-listed species (Table 3.5-1): *G. vastus* (sample size = 130), *G. abbreviatus* (sample size = 1), and *S. amnicola* (sample size = 7). Data were pooled into two species groups (Table 3.5-2): Gomphus Group (*Gomphus* sp. and *D. spinosus*; sample size = 137) and Stylurus Group (*S. amnicola* and *S. spiniceps*; sample size = 32). Some adjustments were made to the 2015 dataset based on the 2016 observations. In 2016, the duration from the start of eclosure to when the individual was completely free from the larval exoskeleton (termed "Start to Free" in the analysis) was recorded for 157 individuals and averaged 16 minutes (range = 7 to 30 minutes). Based on what we learned about the odonate behavior preceding and during eclosure over the two years of study (see Discussion section), we adjusted the 2015 dataset by replacing missing or anomalous values with the 30-minute maximum speed that was recorded in 2016. Also, one anomalous data point for the duration

from when the teneral was free from the larval exoskeleton to when the adult flew away (termed "Free to Flight" in the analysis) was removed from the analysis [3:55, which was almost 2.5 hours longer than the next-longest data point].

For the combined 2015-2016 data, the average duration of "Start to Free" (i.e., start of eclosure to free from the larval exoskeleton) was 18 minutes (range: 7 to 30 minutes) (Table 3.5-2). The average duration of "Free to Flight" (i.e., free from larval exoskeleton to flight) was 39 minutes (range: 7 to 96 minutes). Together, these two time periods comprise the critical time period from when a larva stops to eclose to when it flies away ("Start to Flight"). The average duration of "Start to Flight" was 58 minutes and ranged from 24 to 126 minutes for all species combined. Variation among species seemed related more to sample sizes than species-specific differences. Among species or species groups with relatively large sample sizes, "Start to Flight" durations ranged from 28 to 105 minutes for *G. vastus* (sample size = 122), from 24 to 85 minutes for *S. spiniceps* (sample size = 25), from 28 to 118 minutes for the Gomphus Group (sample size = 129), and from 24 to 85 minutes for the Stylurus Group (sample size = 31).

3.6 Critical Protective Rates

Data derived from the hydraulic models for the TFI and downstream from Cabot Station included hourly water surface elevation for the daily period from 4am to 5pm, from May 15 to August 15 to correspond with odonate emergence periods. For each hour within the target period, change in water surface elevation was computed and only the positive rate of change values (i.e., water levels rising) were included in the analysis. The maximum positive hourly rate of change was determined for each day; from this data set the mean, standard deviation, minimum, 25th percentile, median, 75th and 95th percentile were calculated for each location as shown in Tables 3.6-1 and 3.6-2. Table 3.6-3 presents these same statistics for the bypass reach based on empirical water level data from 2014-2015.

Critical Protective Rates (CPR) (ft/hr) were compared to the 95th percentile of the maximum hourly rate of change (termed MHR-95%) at five representative locations downstream from Cabot Station and seven representative locations throughout the TFI (Tables 3.6-4 and 3.6-5). If the MHR-95% is less than the CPR for a given percentile, then that percent of the population is not likely to be affected.

Table 3.6-4 summarizes the potential effects for state-listed species and groups that may contain one or more state-listed species. The Gomphus Group, which represents the four state-listed *Gomphus* that may occur in the Project area and *D. spinosus*, is mostly not affected because its CPR are higher than the MHR-95% at most sites, except for the bypass reach, where approximately 20-30% of individuals could be affected. MHR-95% is higher than CPR-95% at two sites nearest to Cabot Station, and at the lowermost site in the TFI, indicating approximately 5% of the population may be affected in these areas.

In contrast, for *S. amnicola* the MHR-95% exceeds the CPR-70% at all 14 locations, and also exceeds CPR-50% at the transect nearest to Cabot Station and in the bypass reach, indicating that a large proportion of the *S. amnicola* population may be affected Project-wide due to its tendency to eclose close to the water. For *N. yamaskanensis*, the MHR-95% exceeds the CPR-95% throughout most of the river, except at the downstream-most site (Route 116 Bridge), but only exceed CPR-90% at the transect nearest to Cabot Station and in the lowermost site in TFI. Like other species, a higher proportion of the *N. yamaskanensis* population could be affected in the bypass reach, based on the 2014-2105 data.

For co-occurring species (Table 3.6-5), *O. rupinsulensis* is the most susceptible to water level changes throughout the Project area, with MHR-95% exceeding CPR-50% at both of the bypass reach locations, CPR-70% at 11 locations, and CPR-80% at 13 locations. For *D. spinosus*, MHR-95% exceeds CPR-50% at both sites in the bypass reach, and exceeds CPR-90% at all locations. Although data suggest that *E. princeps* and the Libellulidae Group may be susceptible to water level changes near Cabot Station and in the bypass reach, these taxa were only found in the lentic habitats of Barton Cove and were not found in the bypass reach or downstream from Cabot Station.

Stakeholders expressed interest in the combined effect of Project operations and boat wakes on odonate emergence. This is only an issue in areas of the TFI, not in Barton Cove (a wake-free zone) or downstream from the dam. To assess this, a correction factor of 0.23 ft was added to the MHR-95% for six TFI sites, and then compared to CPRs for species and species groups (Tables 3.6-6 and 3.6-7). This resulted in slightly greater potential effects for all species and species groups.

Table 3.1-1: Odonate Species Collected in the Project Area during Phase 1 (2014), Phase 2 (2015), and Phase 3 (2016) Surveys.

Species	Abbreviation	State-Status	Phase 1 (2014) Survey Site								Phase 2 (2015) Survey Site					Phase 3 (2016) Survey Site								Total
			1	2	3	4	5	6	7	8	1	2	3	4	5	1	2	3	4	5	6	7	8	(2015-2016)
Arigomphus furcifer	ArFu			P							0	0	0	0	0	0	0	0	0	0	0	0	0	0
Basiaeschna janata	BaJa										0	0	0	0	2	0	0	0	0	0	0	0	0	2
Boyeria vinosa	BoVi		P			P	P	P	P	P	58	3	11	6	0	0	0	0	0	0	0	0	0	78
Cordulegaster maculata	CoMa										0	0	0	1	0	0	0	0	0	0	0	0	0	1
Dromogomphus spinosus	DrSp										3	10	1	2	2	0	1	2	0	0	0	0	0	21
Epitheca princeps	EpPr		P	P	P	P	P				0	0	0	1	101	0	0	0	0	0	0	0	0	102
Gomphus abbreviatus	GoAb	Special Concern				P	P	P	P	P	2	4	0	14	0	0	0	0	0	0	0	0	0	20
Gomphus vastus	GoVa	Special Concern				P	P	P	P	P	70	129	2	18	0	0	3	19	53	35	0	19	0	348
Gomphus ventricosus	GoVe	Threatened					P				0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hagenius brevistylus	HaBr										2	1	1	0	0	0	0	0	0	0	0	0	0	4
Libellula sp.	Lisp										0	0	0	0	6	0	0	0	0	0	0	0	0	6
Libellulinae (unidentified)	Li										0	0	0	0	12	0	0	0	0	0	0	0	0	12
Macromia illinoiensis	MaIl		P	P	P	P	P	P	P	P	3	2	6	2	1	0	0	0	0	0	0	0	0	14
Neurocordulia yamaskanensis	NeYa	Special Concern	P	P	P	P	P	P	P	P	3	8	4	6	2	0	0	0	0	0	0	0	0	23
Ophiogomphus rupinsulensis	OpRu					P	P	P	P	P	5	20	0	0	0	0	0	0	0	0	0	0	0	25
Perithemis tenera	PeTe					P	P	P	P	P	0	0	0	0	27	0	0	0	0	0	0	0	0	27
Stylurus amnicola	StAm	Endangered									3	1	5	0	0	0	0	4	0	0	0	0	0	13
Stylurus spiniceps	StSp					P					23	25	9	5	0	0	0	13	8	0	0	0	0	83
										Total	**172**	**203**	**39**	**55**	**153**	**0**	**4**	**38**	**61**	**35**	**0**	**19**	**0**	**779**

Notes:
Species abbreviations are used in subsequent tables and graphs in this report.
Phase 1 surveys sites are listed below. P = Present. Also see Appendix A for maps and additional descriptions of Phase 1 survey sites:

- *Sites 1 – 3: Barton Cove*
- *Site 4: Bypass Reach above and below Rock Dam*
- *Site 5: Downstream from Railroad Bridge*
- *Site 6: Between Railroad Bridge and Third Island*
- *Site 7: Upstream from Third Island*
- *Site 8: Route 116 Bridge, Boat Ramp*

Table 3.2-1: Counts and Summary Statistics for Exuviae (all Species Combined) and Species Richness at each Survey by Sampling Period and by Transect, for the Phase 2 (2015) Quantitative Sampling

Parameter	Number of Individuals						Number of Species					
	Survey Site						Survey Site					
	2015-1	2015-2	2015-3	2015-4	2015-5	Total	2015-1	2015-2	2015-3	2015-4	2015-5	Total
Sampling Period												
1	5	19	0	10	30	64	2	2	0	2	2	5
2	36	122	3	17	15	193	2	4	2	3	4	7
3	35	15	7	4	24	85	4	3	4	4	3	9
4	27	11	7	7	34	86	8	5	4	4	6	12
5	24	26	8	9	11	78	4	5	4	5	4	11
6	35	9	10	6	24	84	2	3	4	3	3	9
7	7	0	4	1	15	27	3	0	2	1	3	6
8	3	1	0	1	0	5	1	1	0	1	0	2
Total	172	203	39	55	153	622	10	10	8	9	8	16
Average	21.5	25.4	4.9	6.9	19.1	77.8	3.3	2.9	2.5	2.9	3.1	7.6
SD	14.32	40.00	3.72	5.28	11.04	55.42	2.19	1.81	1.77	1.46	1.73	3.29
Minimum	3	0	0	1	0	5	1	0	0	1	0	2
Maximum	36	122	10	17	34	193	8	5	4	5	6	12
Transect												
1	28	40	5	6	12		6	5	3	3	2	
2	20	23	15	6	20		3	7	5	4	4	
3	25	18	7	3	82		4	6	4	2	5	
4	23	34	6	6	12		8	7	5	3	3	
5	48	51	1	13	17		6	5	1	4	4	
6	22	37	3	21	4		6	6	3	6	2	
Total	166	203	37	55	147		10	10	8	9	8	
Average	27.7	33.8	6.2	9.2	24.5		5.5	6.0	3.5	3.7	3.3	
SD	10.33	11.92	4.83	6.68	28.69		1.76	0.89	1.52	1.37	1.21	
Minimum	20	18	1	3	4		3	5	1	2	2	
Maximum	48	51	15	21	82		8	7	5	6	5	

Species counts are shown in Table 3.2-2 and Appendix E.

Table 3.2-2: Species Counts at Each Site and for Each Sampling Period for the Phase 2 (2015) Quantitative Sampling

		Species																	
Site	**Period**	**BaJa**	**BoVi**	**CoMa**	**DrSp**	**EpPr**	**GoAb**	**GoVa**	**HaBr**	**Lisp**	**Li**	**MaII**	**NeYa**	**OpRu**	**PeTe**	**StAm**	**StSp**	**Total**	**# Species**
1	1	0	0	0	0	0	2	0	0	0	0	0	0	3	0	0	0	5	2
1	2	0	0	0	0	0	0	34	0	0	0	0	0	2	0	0	0	36	2
1	3	0	2	0	0	0	0	30	1	0	0	0	2	0	0	0	0	35	4
1	4	0	12	0	3	0	0	5	1	0	0	1	1	0	0	3	1	27	8
1	5	0	11	0	0	0	0	1	0	0	0	1	0	0	0	0	11	24	4
1	6	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	10	35	2
1	7	0	5	0	0	0	0	0	0	0	0	1	0	0	0	0	1	7	3
1	8	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1
1	ALL	0	58	0	3	0	2	70	2	0	0	3	3	5	0	3	23	172	10
2	1	0	0	0	0	0	3	0	0	0	0	0	0	16	0	0	0	19	2
2	2	0	0	0	0	0	1	111	0	0	0	0	6	4	0	0	0	122	4
2	3	0	0	0	2	0	0	11	0	0	0	0	2	0	0	0	0	15	3
2	4	0	0	0	4	0	0	3	1	0	0	0	0	0	0	1	2	11	5
2	5	0	2	0	4	0	0	1	0	0	0	1	0	0	0	0	18	26	5
2	6	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	5	9	3
2	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	8	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1
2	ALL	0	3	0	10	0	4	129	1	0	0	2	8	20	0	1	25	203	10
3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	2	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	3	2
3	3	0	0	0	0	0	0	1	1	0	0	4	1	0	0	0	0	7	4
3	4	0	3	0	0	0	0	0	0	0	0	0	1	0	0	2	1	7	4
3	5	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2	4	8	4
3	6	0	4	0	0	0	0	0	0	0	0	2	0	0	0	1	3	10	4
3	7	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	2
3	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	ALL	0	11	0	1	0	0	2	1	0	0	6	4	0	0	5	9	39	8
4	1	0	0	1	0	0	9	0	0	0	0	0	0	0	0	0	0	10	2
4	2	0	0	0	0	0	4	12	0	0	0	0	1	0	0	0	0	17	3
4	3	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	4	4
4	4	0	1	0	1	0	0	4	0	0	0	0	1	0	0	0	0	7	4
4	5	0	2	0	0	0	0	1	0	0	0	2	3	0	0	0	1	9	5
4	6	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	4	6	3
4	7	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
4	8	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
4	ALL	0	6	1	2	1	14	18	0	0	0	2	6	0	0	0	5	55	9
5	1	1	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0	30	2
5	2	1	0	0	0	12	0	0	0	0	0	1	1	0	0	0	0	15	4
5	3	0	0	0	1	22	0	0	0	0	0	0	0	0	1	0	0	24	3
5	4	0	0	0	1	17	0	0	0	2	6	0	1	0	7	0	0	34	6
5	5	0	0	0	0	3	0	0	0	2	1	0	0	0	5	0	0	11	4
5	6	0	0	0	0	9	0	0	0	0	5	0	0	0	10	0	0	24	3
5	7	0	0	0	0	9	0	0	0	2	0	0	0	0	4	0	0	15	3
5	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	ALL	2	0	0	2	101	0	0	0	6	12	1	2	0	27	0	0	153	8
ALL	1	1	0	1	0	29	14	0	0	0	0	0	0	19	0	0	0	64	5
ALL	2	1	0	0	0	12	5	158	0	0	0	1	10	6	0	0	0	193	7
ALL	3	0	2	0	3	23	1	43	2	0	0	4	6	0	1	0	0	85	9
ALL	4	0	16	0	9	17	0	12	2	2	6	1	4	0	7	6	4	86	12
ALL	5	0	16	0	5	3	0	3	0	2	1	4	3	0	5	2	34	78	11
ALL	6	0	31	0	1	9	0	3	0	0	5	2	0	0	10	1	22	84	9
ALL	7	0	9	0	0	9	0	0	0	2	0	1	0	0	4	0	2	27	6
ALL	8	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5	2
ALL	ALL	2	78	1	18	102	20	219	4	6	12	14	23	25	27	9	62	622	16

Species are abbreviated as in Table 3.1-1. Appendix E shows species counts by sampling period and transect.

Table 3.2-3: 2016 Survey Dates and Durations, Number of Eclosure Observations, and Weather.

Date	Site	Start time	End Time	# Observations	Air Temp (°F)	Weather
5/27/2016	3	12:00	13:30	0	80	Sunny
5/27/2016	5	7:00	11:00	0	70	Mostly Sunny
5/31/2016	2	11:00	13:00	0	80	Mostly Sunny
5/31/2016	5	7:00	10:30	0	70	Fog then Sun
6/2/2016	3	6:30	15:30	13	70	Fog then Sun
6/3/2016	2	7:00	13:00	3	75	Sunny
6/4/2016	3	8:00	15:00	41	80	Fog then Sun
6/4/2016	4	8:00	14:00	22	80	Fog then Sun
6/4/2016	8	6:30	7:30	0	65	Overcast
6/6/2016	5	9:25	16:00	38	75	Mostly Sunny
6/6/2016	7	7:00	14:00	19	80	Sunny
6/7/2016	3,4	7:00	8:45	0	65	Partly Sunny
6/9/2016	7	11:00	13:00	0	60	Partly Sunny
6/9/2016	8	7:00	10:30	0	60	Partly Sunny
6/11/2016	1	7:30	10:30	0	65	Overcast
6/13/2016	3	10:30	11:30	0	60	Partly Sunny
6/13/2016	5	7:30	10:00	0	60	Fog then Mostly Sunny
6/14/2016	2	10:30	12:00	0	65	Sunny
6/14/2016	7	7:30	10:00	0	65	Sunny
6/17/2016	2	7:00	10:20	1	70	Mostly Sunny
6/17/2016	3	10:40	12:00	0	75	Mostly Sunny
6/17/2016	3	14:30	15:00	0	75	Mostly Sunny
6/20/2016	3	8:20	10:30	0	75	Sunny
6/20/2016	4	6:00	8:15	0	70	Fog then Sun
6/20/2016	4	10:35	11:15	2	80	Sunny
6/20/2016	4	16:30	17:00	0	80	Sunny
6/22/2016	4	11:00	11:30	0	70	Partly Sunny
6/22/2016	5	8:00	10:40	0	65	Fog then Partly Sunny
6/24/2016	3	7:45	9:00	0	65	Sunny
6/24/2016	4	9:05	13:20	0	75	Sunny
6/24/2016	7	6:00	12:30	0	75	Sunny
6/27/2016	4	7:30	15:30	6	80	Mostly Sunny
7/5/2016	3	12:30	18:00	4	80	Mostly Sunny
7/6/2016	3	12:30	16:30	4	90	Mostly Sunny
7/6/2016	6	11:00	12:00	0	85	Sunny
7/6/2016	7	9:00	10:45	0	80	Sunny
7/7/2016	2	9:00	12:15	0	80	Overcast
7/7/2016	4	8:45	15:00	6	80	Overcast
7/13/2016	4	9:00	12:30	5	80	Sunny

Table 3.3-1: Comparison of Median Vertical Climb Heights and Horizontal Climb Distances for Odonate Species and Species Groups that were observed in 2015 and 2016.

Species/Statistic	Vertical Height		Horizontal Distance	
	2015	2016	2015	2016
All Species				
Sample Size	621	156	617	156
Median	5.0	7.2	11.5	18.7
Gomphus vastus				
Sample Size	219	129	219	129
Median	6.8	7.8	11.2	20.7
Dromogomphus spinosus				
Sample Size	18	3	18	3
Median	3.7	2.8	10.7	14.9
Gomphus Group				
Sample Size	257	132	257	132
Median	6.7	7.7	11.0	19.9
Stylurus amnicola				
Sample Size	8	4	8	4
Median	2.5	0.4	4.4	2.2
Stylurus spiniceps				
Sample Size	62	20	62	20
Median	3.8	3.1	12.9	12.5
Stylurus Group				
Sample Size	70	24	70	24
Median	3.7	2.3	11.5	12.1

Table 3.3-2: Summary of Vertical Crawl Heights, Critical Height Percentiles, and Horizontal Crawl Distances for Odonate Species and Species Groups Collected in 2015 and 2016.

Statistic	Species														Groups			
	BaJa	BoVi	DrSp	EpPr	GoAb	GoVa	HaBr	Li	MaIl	NeYa	OpRu	PeTe	StAm	StSp	Aeshnidae	Gomphus	Libellulidae	Stylurus
Vertical Crawl Height (ft)																		
Sample Size	2	78	21	102	20	348	4	18	14	23	25	27	13	83	80	389	45	100
Average	6.5	5.9	5.2	4.2	7.1	7.4	5.7	3.1	7.1	6.6	3.3	2.5	2.4	4.0	5.9	7.2	2.8	3.9
StDev	1.27	2.88	4.37	2.17	2.69	3.33	4.53	1.59	4.88	4.66	2.45	1.31	2.39	3.57	2.85	3.39	1.45	3.51
Minimum	5.6	0.3	0.1	0.6	3.0	0.0	0.1	0.5	0.2	0.2	0.4	0.3	0.0	0.0	0.3	0.0	0.3	0.0
25th Percentile	6.1	4.2	2.4	2.4	5.2	4.8	3.3	2.2	3.4	3.3	1.2	1.9	0.4	1.6	4.3	4.7	1.9	1.2
Median	6.5	5.5	2.8	4.0	7.1	7.3	5.9	2.9	7.0	5.6	3.5	2.4	2.2	3.4	5.5	7.2	2.5	3.3
75th Percentile	7.0	7.4	8.8	5.8	8.6	9.6	8.2	3.9	10.4	9.3	4.3	2.8	2.9	5.5	7.4	9.5	3.1	5.4
Maximum	7.4	14.5	13.3	10.0	13.8	17.5	10.8	6.6	17.5	17.5	11.5	6.5	7.2	22.2	14.5	17.5	6.6	22.2
Critical Height Percentiles (ft)																		
5%	5.69	1.51	0.13	0.93	3.35	1.81	0.77	1.27	0.75	1.12	0.43	1.07	0.15	0.09	1.52	1.69	1.00	0.08
10%	5.78	2.26	0.15	1.46	3.51	3.07	1.42	1.47	1.60	1.71	0.79	1.46	0.27	0.18	2.30	2.81	1.44	0.17
20%	5.96	3.96	1.84	2.12	5.05	4.42	2.70	1.96	3.14	2.69	1.11	1.74	0.37	1.01	3.99	4.15	1.78	0.67
30%	6.14	4.53	2.50	2.60	5.22	5.59	3.99	2.41	3.67	4.03	1.31	1.92	0.75	2.24	4.58	5.26	1.94	2.14
50%	6.50	5.47	2.83	4.00	7.08	7.34	5.88	2.90	6.98	5.63	3.45	2.40	2.17	3.35	5.51	7.23	2.50	3.29
Horizontal Crawl Distance (ft)																		
Sample Size	2	77	21	102	20	348	4	18	14	23	25	27	13	83	79	389	45	96
Average	13.6	17.2	11.8	12.4	12.8	17.1	15.5	11.0	16.5	13.2	10.2	7.7	6.5	14.2	17.1	16.6	9.0	13.1
StDev	0.23	9.86	7.26	7.62	10.99	11.62	10.05	6.21	13.23	10.52	6.95	5.18	6.45	11.34	9.75	11.47	5.78	11.10
Minimum	13.5	1.5	0.3	0.3	1.0	0.2	0.5	3.6	1.3	0.7	0.0	1.3	0.0	0.0	1.5	0.2	1.3	0.0
25th Percentile	13.5	11.5	6.9	7.9	3.4	8.7	15.1	5.0	5.8	4.5	5.2	3.6	1.3	3.9	11.5	8.4	4.3	2.9
Median	13.6	16.2	11.2	11.6	8.2	14.4	20.2	11.2	13.0	12.1	8.5	6.7	4.1	12.5	16.1	13.8	7.9	11.8
75th Percentile	13.7	22.3	16.6	13.1	23.0	24.3	20.6	13.5	25.0	20.3	13.5	11.3	12.5	22.6	22.3	23.3	12.8	21.7
Maximum	13.8	58.9	24.6	39.4	33.1	49.9	21.3	24.9	43.3	37.1	28.5	20.0	18.7	58.1	58.9	49.9	24.9	58.1

Note: Aeshnidae combines Basiaeschna janata (BaJa) and Boyeria vinosa (BoVi). Libellulidae combines Libellulinae (Li) and Perithemis tenera (PeTe). Gomphus combines Gomphus vastus (GoVa), Gomphus abbreviatus (GoAb), and Dromogomphus spinosus (DrSp). Stylurus combines Stylurus amnicola (StAm) and Stylurus spiniceps (StSp).

Table 3.4-1: Eclosure substrate preference for odonates collected in 2015 and 2016, expressed as percent preference.

Species	Sample Size	Eclosure Substrate*					
		Soil	Rock	Root	Tree	Herb	Detritus
Basiaeschna janata	2	0.0	0.0	50.0	0.0	50.0	0.0
Boyeria vinosa	78	31.3	8.3	16.7	26.0	16.7	1.0
Cordulegaster maculata	1	0.0	0.0	0.0	100.0	0.0	0.0
Dromogomphus spinosus	21	41.7	8.3	33.3	0.0	12.5	4.2
Epitheca princeps	102	6.5	14.0	5.6	5.6	55.1	13.1
Gomphus abbreviatus	20	55.0	15.0	5.0	25.0	0.0	0.0
Gomphus vastus	348	39.1	1.0	25.5	20.2	10.2	3.9
Hagenius brevistylus	4	100.0	0.0	0.0	0.0	0.0	0.0
Libellula sp.	6	16.7	0.0	0.0	0.0	66.7	16.7
Libellulinae (unidentified)	12	5.9	0.0	0.0	5.9	64.7	23.5
Macromia illinoiensis	14	46.7	20.0	0.0	0.0	26.7	6.7
Neurocordulia yamaskanensis	23	20.0	20.0	4.0	32.0	20.0	4.0
Ophiogomphus rupinsulensis	25	54.2	25.0	4.2	8.3	4.2	4.2
Perithemis tenera	27	0.0	30.3	3.0	6.1	30.3	30.3
Stylurus amnicola	13	71.4	0.0	21.4	0.0	7.1	0.0
Stylurus spiniceps	83	53.8	2.8	26.4	4.7	12.3	0.0

**Soil = silt and sand; Rock = gravel, cobble, and larger; Root = tree roots, Tree = tree trucks and large fallen trees, Herb = herbaceous vegetation and vines, Detritus = leaf litter and other organic debris*

Table 3.4-2: Summary of Habitat Parameters Recorded at Each Transect Sampled During the Phase 2 Quantitative Odonate Surveys.

Site	Trans	Latitude	Longitude	Slope*	Embed**	Emergence/Eclosure Habitat Types***											
						Silt	Sand	Grav	LRock	Root	CWood	Detr	Emerg	Moss	Herb	Shrub	TreeTr
1	1	42.46716	-72.58354	2	10	95	0	0	5	0	0	0	0	0	10	60	P
	2	42.46734	-72.58342	3	10	85	0	0	15	0	0	0	0	T (2)	5	5	P
	3	42.46756	-72.58334	2	0	40	0	40	20	0	0	0	0	0	5	10	P
	4	42.46822	-72.58284	1	0	95	0	0	0	0	5	0	0	0	60	5	0
	5	42.46952	-72.58181	1	0	100	0	0	0	0	0	0	0	5	30	15	P
	6	42.46975	-72.58160	1	30	75	0	0	25	0	0	0	0	10	35	5	P
2	1	42.53894	-72.56413	2	0	60	0	15	5	20	0	0	0	10	10	5	P
	2	42.53898	-72.56411	2	0	70	0	15	5	10	0	0	0	10	10	0	0
	3	42.53903	-72.56407	2	0	50	0	30	10	10	0	0	0	10	10	0	0
	4	42.53907	-72.56402	2	0	65	0	15	5	15	0	0	0	10	5	0	P
	5	42.53916	-72.56393	2	0	80	0	10	0	5	5	0	0	10	30	5	0
	6	42.53953	-72.56365	2	0	80	0	5	0	15	0	0	0	10	30	15	P
3	1	42.58020	-72.57455	2	0	90	0	0	5	5	0	0	0	T (2)	50	15	P
	2	42.58018	-72.57471	3	0	20	0	5	75	0	0	0	0	0	5	T (2)	P
	3	42.58021	-72.57484	2	0	85	0	0	5	10	0	0	0	10	20	T (2)	P
	4	42.57983	-72.57603	2	0	85	0	0	0	10	5	0	0	5	40	30	P
	5	42.57974	-72.57624	2	0	60	10	0	0	25	5	0	0	T (2)	10	15	P
	6	42.57958	-72.57699	1	0	95	0	0	0	0	5	0	0	0	30	15	0
4	1	42.59332	-72.58211	1	0	60	40	0	0	0	0	0	0	0	30	5	P
	2	42.59370	-72.58189	1	0	70	25	0	0	0	5	0	0	5	30	5	P
	3	42.59497	-72.57996	1	0	20	0	20	60	0	0	0	0	5	20	5	P
	4	42.59499	-72.57924	1	0	50	30	20	0	0	0	0	0	T (2)	20	5	P
	5	42.59515	-72.57871	1	0	80	0	0	10	10	0	0	0	15	20	10	P
	6	42.59543	-72.57861	3	0	0	0	0	95	5	0	0	0	35	T (2)	T (2)	P
5	1	42.60600	-72.53146	1	0	50	30	0	0	0	10	10	60	0	0	20	0
	2	42.60591	-72.53139	1	0	60	25	0	0	0	5	10	80	0	0	20	0
	3	42.60512	-72.53125	2	0	50	0	10	30	0	0	10	0	5	25	20	0
	4	42.60408	-72.53344	3	60	50	0	5	35	0	10	60	0	10	15	T (2)	P
	5	42.60401	-72.53371	3	0	40	0	10	50	0	0	0	0	25	10	10	P
	6	42.60363	-72.53384	2	0	5	0	5	90	0	0	0	0	0	5	5	0

**Slope = 1: Shallow gradient, 2: Moderate gradient, 3: Steep gradient. Gradient always variable along the length of each transect.*

*** Embed = percent embeddedness of coarse rock, in 10 percent intervals from 0 (unembedded) to 100 (completely embedded).*

****Substrate Abbreviations: Grav = gravel, LRock = large rock, Root = generally, roots of large woody vegetation, CWood = coarse wood (logs, limbs, etc.), Detr = detritus (leaf litter, etc.), Emerg = emergent aquatic vegetation, such as Typha sp., TreeTr = Tree trunks, T = trace*

Table 3.5-1: Eclosure Duration and Sample Sizes for Odonate Species.

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
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

Table 3.5-2: Eclosure Duration and Sample Sizes for Odonate Species Groups.

Species/Statistic	Eclosure Period		
	Start-Free	Free-Flight	Start-Flight
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

Table 3.6-1. Summary Statistics of Maximum Hourly Rates of Change in WSEL Upstream of Turners Falls Dam, Each Day from May 15 to August 15 for the Years 2000 to 2015.

Statistic	Maximum Hourly Rates of Change in Water Surface Elevation (ft/hr)						
	HEC-RAS Transect No.						
	2895	14877	25845	31191	48441	56235	70507
Mean	0.43	0.41	0.43	0.41	0.35	0.33	0.32
StDev	0.26	0.24	0.20	0.18	0.17	0.17	0.17
Lowest Max	0.00	0.02	0.03	0.02	0.00	0.00	0.00
25th Percentile	0.29	0.27	0.30	0.28	0.23	0.22	0.20
Median	0.40	0.37	0.41	0.39	0.32	0.31	0.30
75th Percentile	0.50	0.50	0.53	0.50	0.44	0.42	0.41
95th Percentile	0.89	0.81	0.74	0.72	0.66	0.65	0.66

Notes: Data reflects peak emergence period only, between 4 am to 5 pm. Year 2010 not included.

Table 3.6-2. Summary Statistics of Maximum Hourly Rates of Change in WSEL Downstream of Cabot Station, Each Day from May 15 to August 15 for the Years 2008 to 2015.

Statistic	Maximum Hourly Rates of Change in Water Surface Elevation (ft/hr)				
	HEC-RAS Transect No.				
	109.52	113.17	115.07	116.64	118.51
Mean	0.18	0.26	0.30	0.39	0.57
StDev	0.14	0.20	0.21	0.27	0.39
Lowest Max	0.00	0.00	0.00	0.00	0.00
25th Percentile	0.07	0.11	0.14	0.19	0.26
Median	0.16	0.24	0.28	0.36	0.52
75th Percentile	0.28	0.39	0.44	0.57	0.83
95th Percentile	0.45	0.62	0.65	0.85	1.25

Note: Data reflects peak emergence period only, between 4 am to 5 pm. Year 2010 not included.

Table 3.6-3. Summary Statistics of Maximum Hourly Rates of Change in WSEL in Bypass Reach, Each Day from May 15 to August 15 for the Years 2014 to 2015.

Statistic	Maximum Hourly Rates of Change in Water Surface Elevation (ft/hr)	
	Water Level Logger Data	
	Above Rock Dam	Below Rock Dam
Mean	0.73	0.91
StDev	1.16	0.79
Lowest Max	0.01	0.02
25th Percentile	0.04	0.37
Median	0.20	0.75
75th Percentile	0.92	1.14
95th Percentile	3.02	2.54

Note: Data reflects peak emergence period only, between 4 am to 5 pm.

Table 3.6-4: Risk assessment for state-listed species and species groups based on Critical Protective Rates (CPR-95%) and Maximum Hourly Rate of Change (MHR-95%) at sites throughout the Project area.

MHR-95% Exceeds CPR at that percentile			Maximum Hourly Rate of Change (ft/hr): 95th Percentile (MHR-95%)												
			Downstream from Cabot Station					Bypass Reach		Turners Falls Impoundment					
			HEC-RAS Transect (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**														
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. yamaskanensis	CPR-95%	**0.56**														
	CPR-90%	**0.86**														
	CPR-80%	**1.34**														
	CPR-70%	**2.02**														
	CPR-50%	**2.82**														

Table 3.6-5: Risk assessment for co-occurring species and species groups based on Critical Protective Rates (CPR-95%) and Maximum Hourly Rate of Change (MHR-95%) at sites throughout the Project area.

MHR-95% Exceeds CPR at that percentile			Maximum Hourly Rate of Change (ft/hr): 95th Percentile (MHR-95%)												
			Downstream from Cabot Station					Bypass Reach		Turners Falls Impoundment					
			HEC-RAS Transect (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**
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**														
	CPR-90%	**0.80**														
	CPR-80%	**1.57**														
	CPR-70%	**1.83**														
	CPR-50%	**3.49**														
E. princeps	CPR-95%	**0.47**														
	CPR-90%	**0.73**														
	CPR-80%	**1.06**														
	CPR-70%	**1.30**														
	CPR-50%	**2.00**														
Aeshnidae Group	CPR-95%	**0.76**														
	CPR-90%	**1.15**														
	CPR-80%	**1.99**														
	CPR-70%	**2.29**														
	CPR-50%	**2.76**														
Libellulidae Group	CPR-95%	**0.50**														
	CPR-90%	**0.72**														
	CPR-80%	**0.89**														
	CPR-70%	**0.97**														
	CPR-50%	**1.25**														

Table 3.6-6: Risk assessment for state-listed species and species groups at sites in the TFI, with a factor of 0.23 ft added to the MHR-95% to account for potential added effects of boat wakes.

MHR-95% Exceeds CPR at that percentile			**MHR-95%** Turners Falls Impoundment HEC-RAS Transect (Downstream to Upstream)					
	Critical Protective Rate		14877	25845	31191	48441	56235	70507
Species/Group	Percentile	Value	**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**						
	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**						
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. yamaskanensis	CPR-95%	**0.56**						
	CPR-90%	**0.86**						
	CPR-80%	**1.34**						
	CPR-70%	**2.02**						
	CPR-50%	**2.82**						

Note: Transect 2895 was not used in the boat wake analysis because it is located in Barton Cove, a no-wake zone.

Table 3.6-7: Risk assessment for co-occurring odonate species and groups at sites in the TFI, with a factor of 0.23 ft added to the MHR-95% to account for potential added effects of boat wakes.

MHR-95% Exceeds CPR at that percentile			MHR-95% Turners Falls Impoundment HEC-RAS Transect (Downstream to Upstream)					
	Critical Protective Rate		14877	25845	31191	48441	56235	70507
Species/Group	**Percentile**	**Value**	**1.04**	**0.97**	**0.95**	**0.89**	**0.88**	**0.89**
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**						
	CPR-90%	**0.80**						
	CPR-80%	**1.57**						
	CPR-70%	**1.83**						
	CPR-50%	**3.49**						
E. princeps	CPR-95%	**0.47**						
	CPR-90%	**0.73**						
	CPR-80%	**1.06**						
	CPR-70%	**1.30**						
	CPR-50%	**2.00**						
Aeshnidae Group	CPR-95%	**0.76**						
	CPR-90%	**1.15**						
	CPR-80%	**1.99**						
	CPR-70%	**2.29**						
	CPR-50%	**2.76**						
Libellulidae Group	CPR-95%	**0.50**						
	CPR-90%	**0.72**						
	CPR-80%	**0.89**						
	CPR-70%	**0.97**						
	CPR-50%	**1.25**						

Note: Transect 2895 was not used in the boat wake analysis because it is located in Barton Cove, a no-wake zone.

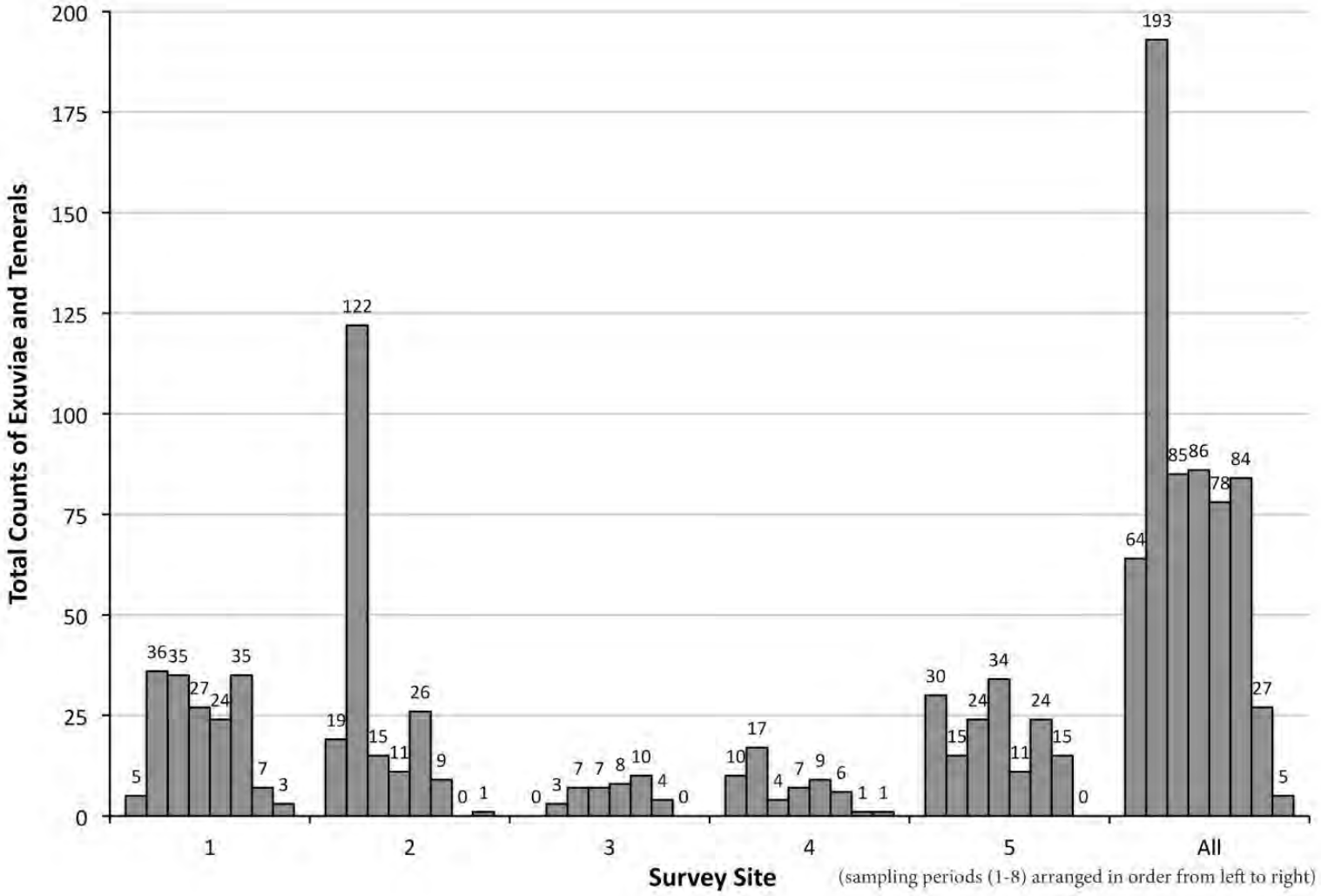


Figure 3.2-1: Total Counts of Odonate Exuviae and Tenerals for each Sampling Period, for all Transects Combined at each of the Survey Sites (2015 Data Only)

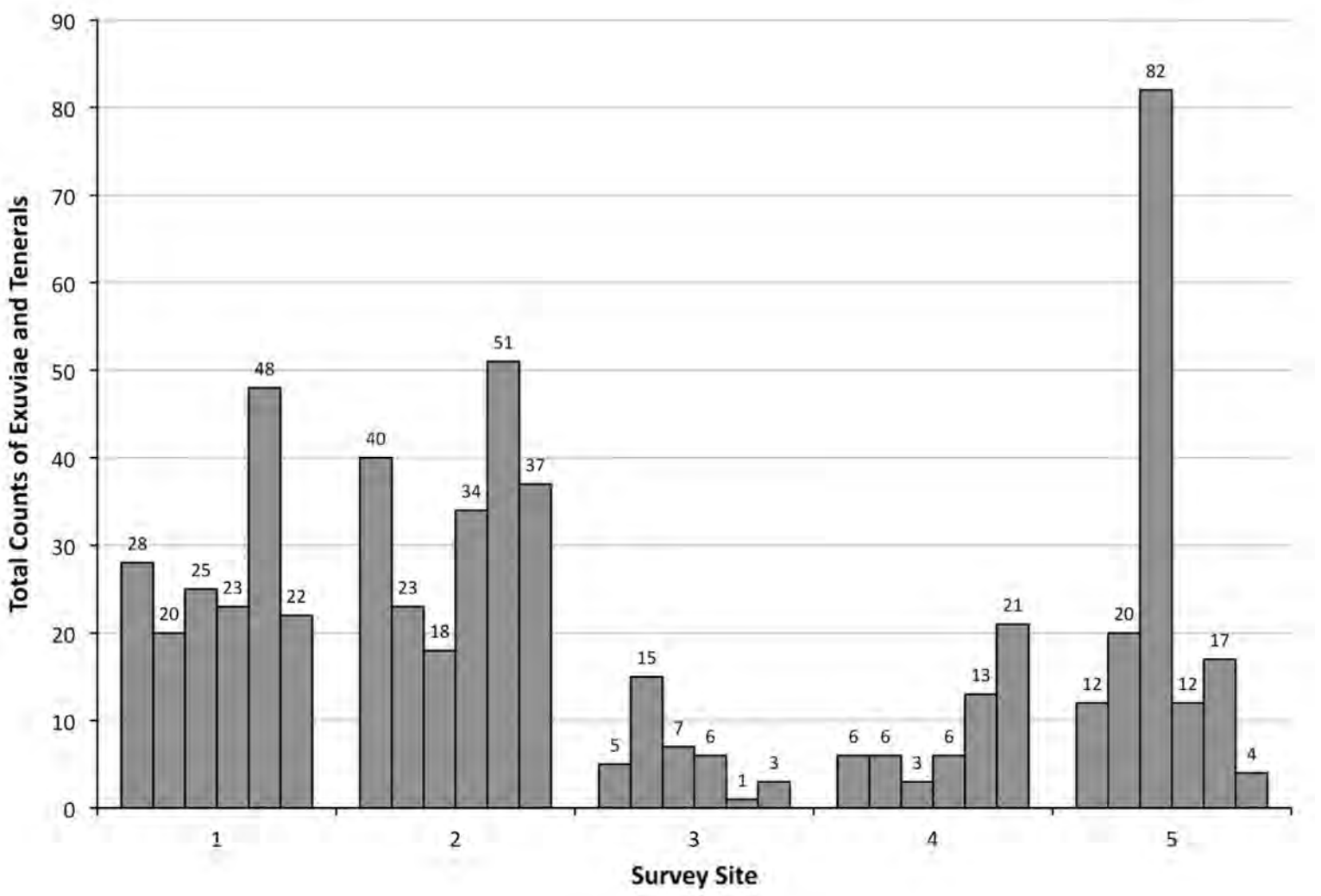


Figure 3.2-2: Counts of Odonate Exuviae and Tenerals in each Transect (all Sampling Periods Combined) at each of the Survey Sites (2015 Data Only)

4 DISCUSSION

4.1 Emergence and Eclosure Behavior

Table 4.1-1 summarizes published emergence and eclosure data for species documented in the Project area. For all species combined (2015-2016), larvae crawled a median horizontal distance of 12.5 ft from the edge of the water before stopping to eclose. Travel distances were generally higher than those reported in 2006 (Morrison *et al.*, 2006) and 2007 (Martin, 2007). However, Martin (2010) reported comparable travel distances for *Gomphus vastus*, especially on non-riprap riverbanks (average = 13.5 ft, standard deviation = 1.14). Martin (2010) reported much lower travel distances for *Stylurus spiniceps* (1.0 ft on non-riprap banks, 0.5 ft on riprap) than we documented in 2015 and 2016 (median = 12.5 ft). We do not understand the large difference between the two studies for *Stylurus spiniceps*. The very limited travel distance data in Martin (2007) for *Dromogomphus spinosus, Hagenius brevistylus, Macromia illinoiensis*, and *Neurocordulia yamaskanensis* are all comparable to our results, indicating travel distances of at least 10-15 ft are common for these riverine species.

Vertical height from the water's surface was not reported in the earlier studies in the Connecticut River. The 2014 qualitative study documented a median vertical distance of 4.0 ft for all species combined, which is similar to the 2015-2016 results of 5.5 ft. Farthest documented travel distance was nearly 60 ft, and greatest vertical height from the water was 22 ft. Although our total number of observations for some species was low, sample sizes adequately describe the range of variation in crawl distance and crawl height for most species that were detected.

The elapsed time from the start of eclosure to first flight is important for understanding potential effects of water level fluctuations. The first step of exiting the water and finding a spot to eclose is less critical because larvae can be inundated, blown back into the water, or can hide or return to the water to avoid predation. We observed numerous instances of larvae returning to the water after being on land for several minutes to several hours; Martin (2010) also reported this behavior. A behavior that became apparent in 2016 was that most larvae crawled onto land overnight or in the pre-dawn hours, but this was just the first phase of their upland travel. By early morning, these larvae were usually hiding under debris or roots, and they remained motionless for several hours until environmental conditions (presumably air temperature and sunlight) triggered a second phase of travel that resulted in the final selection of an eclosure site and the start of eclosure. We observed significant travel distances (>20 ft in some cases) during the second phase of travel. Most of the individuals we observed in 2016 followed this pattern. A small percentage of larvae crawled out of the water and ascended riverbanks in the daylight hours; for these, the travel occurred in just a single phase.

Once the eclosure process begins, the insect is susceptible to rising water levels, wind, waves, and predators. Species that select eclosure sites far enough or high enough from the water to avoid inundation will be most successful at escaping one source of mortality. If larvae select eclosure sites within the zone that may be inundated as water levels rise, then they would need to complete the process and fly away quickly enough to avoid inundation.

It took an average 18 minutes for larvae to completely shed the larval exoskeleton after eclosure began, and an average 39 minutes for tenerals to complete transformation to adults and take their first flight. We collected data on 170 individuals from the beginning of eclosure to flight; average time was 58 minutes, and ranged from 24 to 126 minutes. Figure 4.1-1 shows an example emergence sequence of *Gomphus vastus* from larva to adult; the total elapsed time from the start of eclosure to adult flight for this individual was 73 minutes. Of the species for which some emergence speed data were collected, three were state-listed, including *Gomphus vastus* (130), *Gomphus abbreviatus* (1), and *Stylurus amnicola* (7). Neither our data, nor existing data suggest that the emergence/eclosure speed varies widely among species.

4.2 Potential Effects of Project Operations

In terms of understanding potential effects of water level fluctuations, the concern is for those species and individuals that remain close to the water's edge, especially in areas of the river where daily and hourly water level fluctuations and rates of change are greatest. Individuals at greatest risk of inundation would be those that (1) live in areas where water level fluctuations and rates of change are high, (2) begin to crawl out of the water when water levels are near the daily low, just as the water begins to rise toward its daily peak, (3) crawl only short distances to eclosure sites, and (4) are slow to eclose and fly away. Among the riverine odonate species, those that eclosed closest to the water were *Stylurus amnicola* and *Ophiogomphus rupinsulensis*, suggesting these two species may be more vulnerable than others. Of these, *Stylurus amnicola* is state-listed (Endangered) and *Ophiogomphus rupinsulensis* is not. A small proportion of all species eclosed close enough to the water that inundation during eclosure was a risk to some individuals.

Turners Falls Impoundment

The maximum hourly rates of change in the TFI appear to pose little threat to any of the Gomphus Group, except slight effects (MHR-95% > CPR-90%) for *D. spinosus*. 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. Potential effects of hourly rates of change in the TFI are greatest for *S. amnicola, S. spiniceps*, and *O. rupinsulensis*. Unique to the TFI is boating activity that may create waves that affect odonate eclosure above and beyond the water level changes caused by Project operations. A correction factor of 0.23 ft was added to the MHR-95%, resulting in slightly greater potential for effects for all species and species groups. However, the boat wake analysis should be interpreted cautiously so as to not overstate their effects – the cumulative effect would only occur when water levels are rising and a boat creates a large-magnitude wake. Based on boat wake data collected in the TFI (as part of the Study No. 3.1.2), the boat wakes occur most frequently during peak recreational times (the highest traffic was observed on Sundays at all of the sites and the highest frequency of boats was observed between noon and 8 pm, peaking around 2 pm).

Downstream from Cabot Station

Effects of Project operations on WSEL and rates of change diminish with increasing distance downstream from Cabot Station. At survey site near the Sawmill River, 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*. However, potential effects are higher for those species that eclose closer to the water, notably *S. amnicola, O. rupinsulensis,* and *D. spinosus*.

Bypass Reach

Water level fluctuations and rates of change resulting from Project operations appear to affect odonate emergence in areas of the Connecticut River closest to Cabot Station and in the bypass reach. Based on the WSEL data from 2014-2015, 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, during 2014 and 2015 several relicensing studies were being conducted during which special flow releases were being provided via the Turners Falls Dam in the bypass reach. Examples include the whitewater boating study (July 2014), instream flow study (July 2014), and various manipulations of spillage flow and station generation combinations in association with the adult American Shad study (2015). The flow releases during these studies caused a higher frequency and magnitude of water surface elevation changes than would have been observed under more typical spring and summer conditions.

Precisely which areas of the bypass reach are affected, and to what extent, depend on the timing and magnitude of flows through Cabot Station, Station No. 1, and spill over the Turners Falls Dam. Flows through Cabot Station affect WSELs upstream to, but not above, Rock Dam. Other than spill provided for minimum bypass flows conditions (e.g., 400 cfs), spill events over the Turners Falls Dam during the odonate emergence period are usually associated with large precipitation events rather than Project operations. If water is quickly released through Station No. 1, odonate emergence could be affected in downstream areas of the bypass reach, but specific effects would depend on the timing (time of day or time of year) of such releases.

Conclusions

Water level fluctuations and rates of change may affect odonate emergence in areas of the Connecticut River closest to Cabot Station during the seasonal (May 15-August 15) and daily (4am to 5pm) periods evaluated, which correspond to peak emergence periods for odonates. State-listed odonate species documented in these areas include *Gomphus abbreviatus*, *Gomphus vastus*, *Neurocordulia yamaskanensis*, and *Stylurus amnicola*. Potential effects were highest for *Stylurus amnicola*; at least 30% of the population, and closer to 50% near Cabot Station, were potentially affected based on the MHR-95%. Only a small percentage of the population of *N. yamaskanensis*, *G. vastus*, and the *Gomphus* Group were potentially affected, and primarily close Cabot Station. Among co-occurring riverine species, *S. spiniceps*, *O. rupinsulensis* and *D. spinosus* were likely most affected by water level fluctuations, based on the tendency of these species to eclose closer to the water.

Table 4.1-1: Summary of Emergence and Eclosure Behavior of State-Listed Odonate Species Documented in 2014 and 2015, or that may occur within the Study Reach.

Species*	Emergence & Flight Period**										Eclosure	
	May		June		July		Aug		Sept		Distance	Speed
Gomphus abbreviatus (SC)											Very little information on rare *Gomphus*. Limited data suggest consistent behavior of crawling past the river's edge and variable vertical distances (up to 10+ ft) up the streambank before eclosing on a range of available substrates. *S. amnicola* may crawl shorter distances and eclose on low-gradient shorelines, cobble bars, beaches.	Species-specific data lacking and is likely influenced by air temperature, humidity, and other factors. Most reports are cursory and somewhat consistent, with ~1-2 hours needed to complete the entire process from emergence to adult flight.
Gomphus descriptus (E)												
Gomphus fraternus (E)												
Gomphus quadricolor (E)												
Gomphus vastus (SC)												
Gomphus ventricosus (T)												
Stylurus amnicola (E)												
Neurocordulia yamaskanensis (SC)											May crawl farther up banks and climb trees	

**Includes Massachusetts Endangered Species Act status: E = Endangered, T = Threatened, SC = Special Concern*

***Shading used to distinguish onset of emergence (light gray), peak emergence and flight period (gray), and end of flight period (dark gray)*

Information Sources:

Species-specific data generally lacking; most known for G. vastus, which is comparatively more common in the Connecticut River.

Morrison et al.*, 2001; McLain* et al.*, 2004; McLain* et al.*, 2006; Morrison* et al.*, 2006; Martin, 2007; Martin, 2010.*

Also more general sources: Byers, 1937; Walker, 1958; Needham et al.*, 2000; Glotzhober & McShaffrey, 2002; Nikula & Burne, 2003; and NHESP Fact sheets (2015) (online).*

Figure 4.1-1: Example Emergence Sequence of *Gomphus vastus* from Larva to Adult.

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APPENDIX A:
INTERIM STUDY REPORT (2014)

Relicensing Study 3.3.10

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

Interim Study Report

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)

Prepared for:

FirstLight™
GDF SUEZ

Prepared by:

biodrawversity
ecological consulting and communications

APRIL 2015

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

FERC	Federal Energy Regulatory Commission
FirstLight	FirstLight Hydro Generating Company
ft	feet
hrs	hours
ILP	Integrated Licensing Process
m	meter
NHESP	Natural Heritage and Endangered Species Program
PAD	Pre-Application Document
PSP	Proposed Study Plan
RSP	Revised Study Plan
SD1	Scoping Document 1
SD2	Scoping Document 2
SPDL	Study Plan Determination Letter
VY	Vermont Yankee Nuclear Power Plant

1 INTRODUCTION

FirstLight Hydro Generating Company (FirstLight), a subsidiary of GDF SUEZ North America, Inc., is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the Northfield Mountain and Turners Falls Projects using the FERC's Integrated Licensing Process (ILP). The current licenses for Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018.

As part of the ILP, FERC conducted a public scoping process during which various resource issues were identified. On October 31, 2012, FirstLight filed its Pre-Application Document (PAD) and Notice of Intent with the FERC. The PAD included FirstLight's preliminary list of proposed studies. On December 21, 2012, FERC issued Scoping Document 1 (SD1) and preliminarily identified resource issues and concerns. On January 30 and 31, 2013, FERC held scoping meetings for the Northfield Mountain and Turners Falls Projects. FERC issued Scoping Document 2 (SD2) on April 15, 2013.

FirstLight filed its Proposed Study Plan (PSP) on April 15, 2013 and, per the Commission regulations, held a PSP meeting at the Northfield Visitors Center on May 14, 2013. Thereafter, FirstLight held ten resource-specific study plan meetings to allow for more detailed discussions on each PSP and on studies not being proposed[1]. On June 28, 2013, FirstLight filed with the Commission an Updated PSP to reflect further changes to the PSP based on comments received at the meetings. On or before July 15, 2013, stakeholders filed written comments on the Updated PSP. FirstLight filed a Revised Study Plan (RSP) on August 14, 2013 with FERC addressing stakeholder comments.

On August 27, 2013 Entergy Corp. announced that the Vermont Yankee Nuclear Power Plant (VY), located on the downstream end of the Vernon Impoundment on the Connecticut River and upstream of the two Projects, will close at the end of 2014. With the closure of VY, certain environmental baseline conditions will change during the relicensing study period. On September 13, 2013, FERC issued its first Study Plan Determination Letter (SPDL) in which many of the studies were approved or approved with FERC modification. However, due to the impending closure of VY, FERC did not act on 19 proposed or requested studies pertaining to aquatic resources. RSP Study No. 3.3.10 *Assess Operational Impacts on Emergence of State-Listed Odonates in the Connecticut River,* was one of the studies that FERC did not act upon. The SPDL for these 19 studies was deferred until after FERC held a technical meeting with stakeholders on November 25, 2013 regarding any necessary adjustments to the proposed and requested study designs and/or schedules due to the impending VY closure. FERC issued its second SPDL on the remaining 19 studies, including this study, on February 21, 2014, approving the RSP with certain modifications. Those modifications included:

- Relative to emergence speed, FERC recommended that FirstLight record a minimum of 10 observations per species or species group, provided that 10 individuals from each group are encountered during the emergence study.
- Relative to quantitative survey effort, FERC recommended that FirstLight stratify the survey effort (Surveys of Emergence/Eclosure Behavior), to a minimum of six 2-meter transects in each *available* habitat in each study reach.

This interim report presents the results of the qualitative surveys conducted under Task 3 of Study No. 3.3.10.

[1] The ten meetings were held on May 14, 15, 21, and 22, and June 4, 5, 11, 12, and 14 and August 8.

1.1 Study Goals and Objectives

This study was designed to provide information on the effects of project operations, especially the timing, rate, and magnitude of water level changes, on emerging dragonflies (Insecta: Odonata) in the Connecticut River. This study had two objectives:

1. Synthesis of existing data, supplemented with field surveys, to characterize the assemblage structure and emergence/eclosure behavior of odonates in the project area.

2. Determine if project operations affect the emergence and eclosure success of state-listed odonates, and the potential implications for the odonate assemblage in affected areas.

Two phases of fieldwork were proposed. Phase 1, completed in 2014 and summarized in this interim report, included qualitative surveys of odonate larvae and exuviae at selected sites to determine assemblage structure and to collect basic habitat data. Phase 2, planned for 2015, will include quantitative surveys and observations of emergence/eclosure behavior of odonates to provide data for analyses of the effects of project operations on odonates and their habitat. Phase 2 methods were not finalized in the Revised Study Plan, rather, these details were to be discussed in this interim report and finalized before the 2015 field season commences, in consultation with the Massachusetts Natural Heritage and Endangered Species Program (NHESP).

2 STUDY SITES AND METHODS

Preceding the qualitative field surveys, a scientific collection permit was issued by the NHESP on May 15, 2014.

2.1 Study Sites

Biodrawversity biologists conducted qualitative surveys of odonate larvae and exuviae at four areas (5 sites) between the Turners Falls Dam and the Route 116 Bridge in Sunderland, and one area (3 sites) in the Turners Falls Impoundment near Barton Cove (Figure 2.1-1, Table 2.1-1). Surveys were conducted on June 2, 6, 9, and 20 (2014). Barton Cove and the Route 116 Bridge were also checked twice in May to determine if emergence had begun early. However, the spring of 2014 was cooler than average and river flows were higher than average, and emergence was not detected until early June.

- Representative aquatic and shoreline habitats were surveyed in Barton Cove and on the other side of Campground Point, totaling approximately 350 meters of shoreline (Figure 2.1-1a).
- Representative aquatic and shoreline habitats were surveyed in Turners Falls Project's bypass reach. These surveys were mostly conducted in a ~500 meter reach upstream and downstream from Rock Dam, a natural rock formation with a vertical drop (Figure 2.1-1b).
- Representative aquatic and shoreline habitats were surveyed within two reaches in the area between the Railroad Bridge and Third Island (Montague/Deerfield), totaling approximately 400 meters of shoreline (Figure 2.1-1c). In addition, approximately 150 meters of aquatic and shoreline habitat near the Route 116 Bridge in Sunderland were surveyed in a similar manner (Figure 2.1-1d).

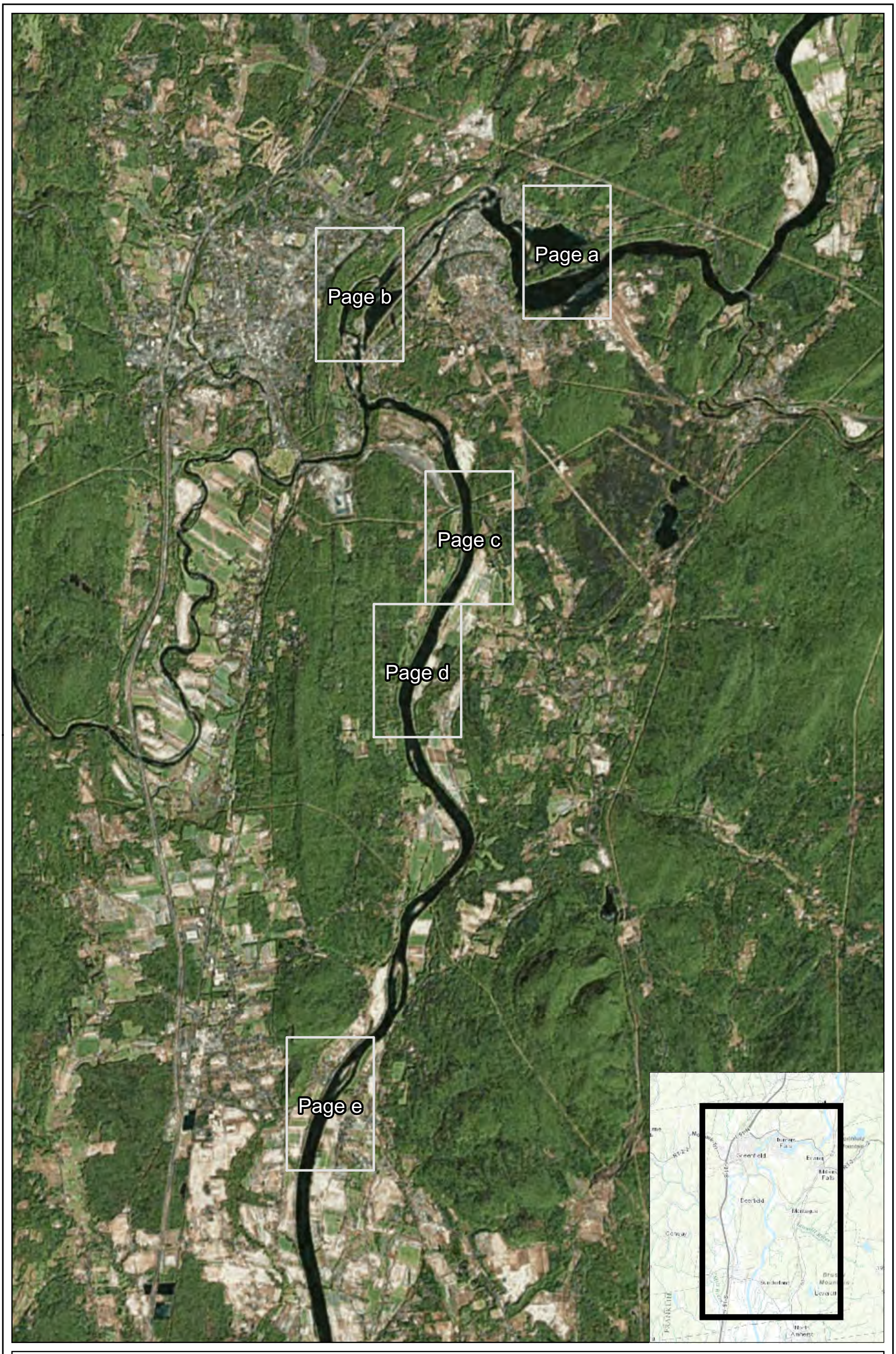
2.2 Methods

Collection methods for larvae included aquatic D-nets and hand picking odonates in the water or on land. Collections were made while wading, snorkeling, and while walking along the riverbank. If present, tenerals or exuviae were collected on the riverbank. For tenerals or exuvia, biologists recorded the vertical and lateral distance from the water's edge, and surface that each was collected on. At each site, aquatic, riparian, and upland habitat parameters were recorded or photographed (Appendix A):

- **Aquatic Parameters**: water depth, water velocity, dominant substrate types, presence and coverage of aquatic vegetation and organic material;
- **Riparian/Upland Parameters**: bank slope, bank height, bank stability, riparian vegetation, tree canopy height and density, land use/land cover.

Table 2.1-1: Locations, dates, and level of effort for each of the eight odonate survey sites in the Connecticut River.

Site	Area	Town	Survey 1	Survey 2	Total Survey Duration (hrs)	Total Linear Survey Distance (m)
1	Barton Cove	Gill	6/2/2014	6/20/2014	3	200
2	Barton Cove	Gill	6/2/2014	-	1	50
3	Barton Cove	Gill	6/2/2014	6/20/2014	2	100
4	Bypass Reach - Rock Dam	Montague	6/6/2014	6/20/2014	6	500
5	Downstream from Railroad Bridge	Montague	6/9/2014	-	3	150
6	Between Railroad Bridge and Third Island	Deerfield	6/9/2014	-	1.5	50
7	Upstream from Third Island	Deerfield	6/9/2014	-	3	200
8	Route 116 Bridge, Boat Ramp	Sunderland	6/20/2014	-	2	150



Northfield Mountain Pumped Storage Project (no. 2485) and Turners Falls Hydroelectric Project (No. 1889)

RELICENSING STUDY 3.3.10
Assess Operational Impacts on Emergence of State-listed Odonates in the Connecticut River

0 0.5 1 2 Miles

N

Figure 2.1-1 Index. Study Sites

Service Layer Credits: Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA,

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Northfield Mountain Pumped Storage Project (no. 2485) and Turners Falls Hydroelectric Project (No. 1889)

RELICENSING STUDY 3.3.10

Assess Operational Impacts on Emergence of State-listed Odonates in the Connecticut River

0 0.05 0.1 0.2 Miles

N

Figure 2.1-1a. Study Sites

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Northfield Mountain Pumped Storage Project (no. 2485) and Turners Falls Hydroelectric Project (No. 1889)

RELICENSING STUDY 3.3.10

Assess Operational Impacts on Emergence of State-listed Odonates in the Connecticut River

0 0.05 0.1 0.2 Miles

Figure 2.1-1b. Study Sites

Service Layer Credits: Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
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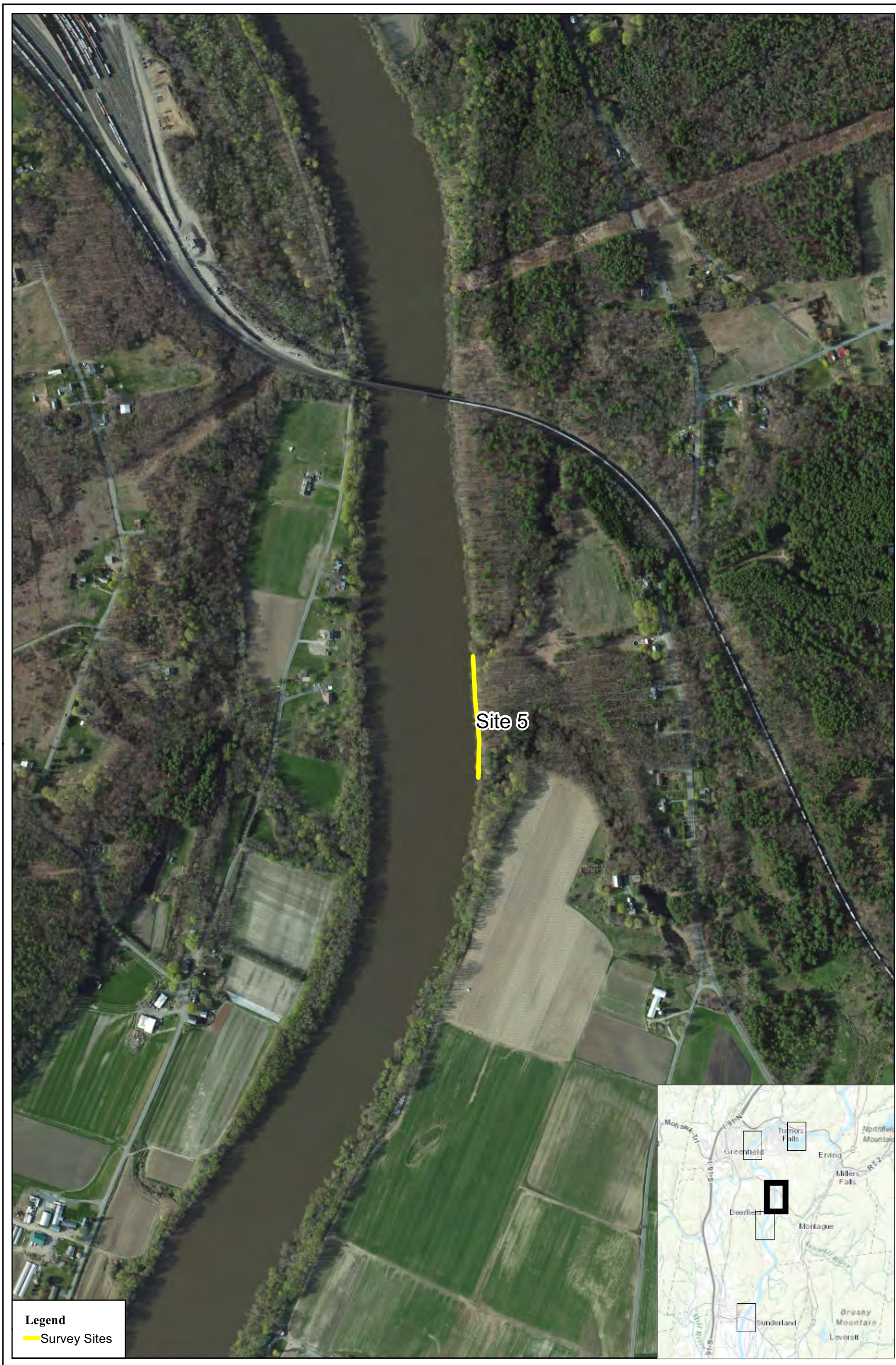

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Northfield Mountain Pumped Storage Project (no. 2485) and Turners Falls Hydroelectric Project (No. 1889)

RELICENSING STUDY 3.3.10

Assess Operational Impacts on Emergence of State-listed Odonates in the Connecticut River

0 0.05 0.1 0.2 Miles

Figure 2.1-1c. Study Sites

Service Layer Credits: Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
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Northfield Mountain Pumped Storage Project (no. 2485) and Turners Falls Hydroelectric Project (No. 1889)

RELICENSING STUDY 3.3.10

Assess Operational Impacts on Emergence of State-listed Odonates in the Connecticut River

0 0.05 0.1 0.2 Miles

Figure 2.1-1d. Study Sites

Service Layer Credits: Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
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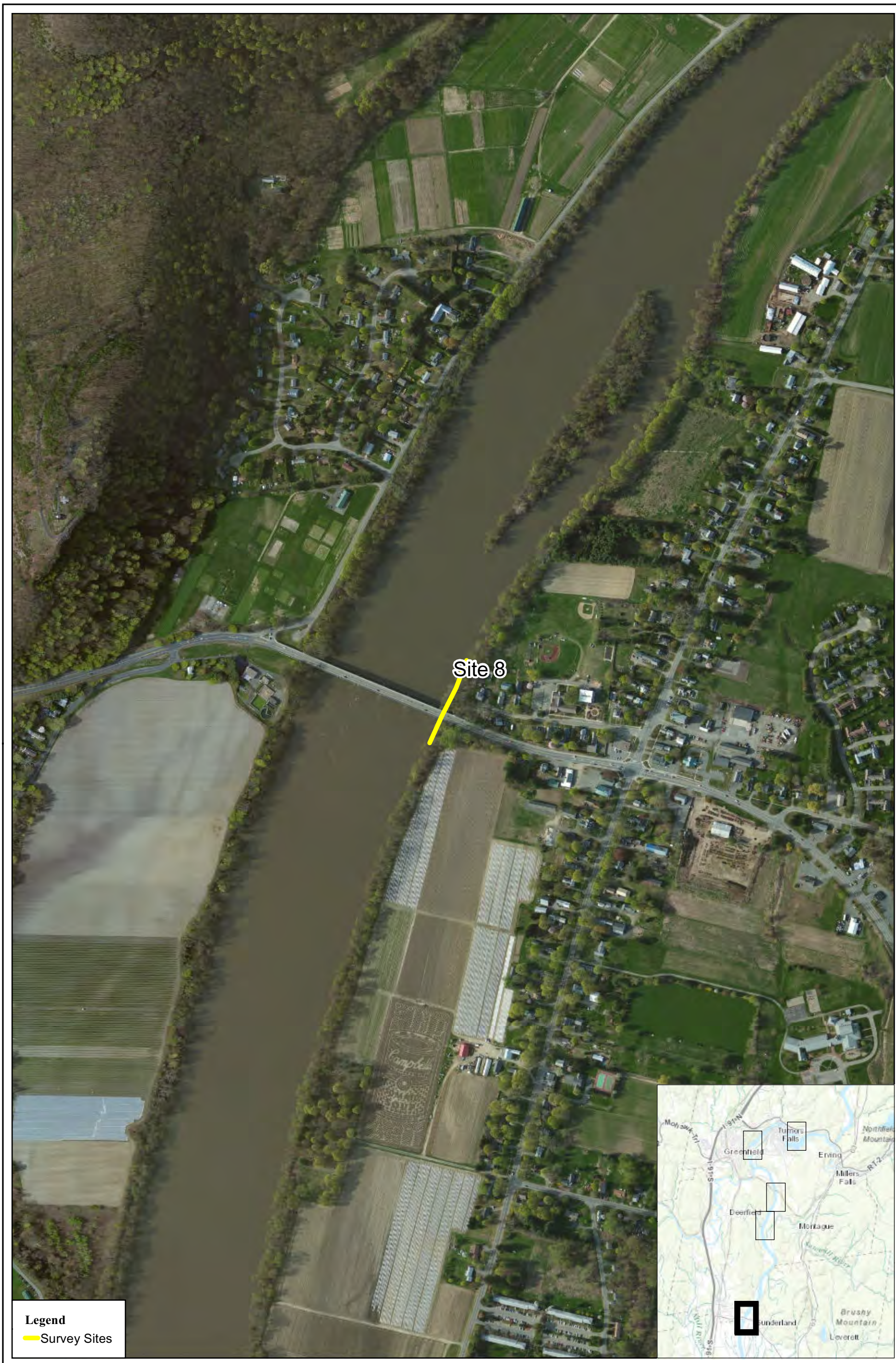

FirstLight™ GDF SUEZ

N

Northfield Mountain Pumped Storage Project (no. 2485) and Turners Falls Hydroelectric Project (No. 1889)

RELICENSING STUDY 3.3.10

Assess Operational Impacts on Emergence of State-listed Odonates in the Connecticut River

0 0.05 0.1 0.2 Miles

Figure 2.1-1e. Study Sites

Service Layer Credits: Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
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3 RESULTS

3.1 Odonate Survey Results

3.1.1 Species Assemblage

Table 3.1.1-1 lists the genera and species collected at each site. *Epitheca princeps*, a species common in lentic habitats, was the most common species collected at Sites 1-3. These sites in the lowermost portion of the Turners Falls Impoundment (Barton Cove) contain mostly lentic habitat with submerged and emergent vegetation. Sites 4-8 were generally more lotic; dominant taxa in these samples included *Gomphus* sp. (mostly *G. vastus*), *Ophiogomphus* (mostly *G. rupinsulensis*), *N. yamaskenensis*, *Boyeria vinosa*, and *Macromia illinoiensis*. There was very little variation in the odonate assemblage among sites 4-8. Species-level identification of some of the Gomphidae, especially *Gomphus* sp. and *Ophiogomphus* sp., is incomplete; this interim report will be updated when these data become available. Most of the target state-listed species for Sites 4-8 were in the genus *Gomphus*. Based on historic survey data, which were generally more complete for the Turners Falls Impoundment, several uncommon species likely occur in these areas but were undetected in 2014.

Table 3.1.1-1: Odonate species documented during the qualitative surveys of larvae and exuviae in June 2014.

	Survey Site							
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Arigomphus furcifer		X						
Boyeria vinosa	X			X	X	X	X	X
Epitheca princeps	X	X	X	X	X			
*Gomphus sp.**			X	X	X	X	X	X
Macromia illinoiensis	X	X	X	X	X	X	X	X
Neurocordulia yamaskenensis	X	X	X	X	X	X	X	X
*Ophiogomphus sp**				X	X	X	X	X
Stylurus spiniceps				X				

*Awaiting final species-level identification by Dr. David Wagner, University of Connecticut. Potential Species: *Gomphus fraternus, Gomphus ventricosus, Gomphus abbreviates, Gomphus vastus, Dromogomphus spinosus, Ophiogomphus rupinsulensis,Gomphus spicatus, Gomphus exilis, Gomphus descriptus, Gomphus lividus*

3.1.2 Emergence and Eclosure

Approximately 250 exuviae were collected across the eight survey sites. These were found on emergent aquatic vegetation only at sites 1 and 3, as this type of emergence substrate was not available at the other sites. Elsewhere, exuviae were found primarily on terrestrial herbaceous vegetation, soil, trees, coarse fallen wood, and rock (Table 3.1.2-1). They were found as high as nine feet above the water's surface (mean = 4.4) and as far as 42 feet from the edge of the water (mean = 12.7). Since these surveys were qualitative and only occurred during the month of June, these distances above the water and from the water's edge are biased, but do provide a range to consider in the next phase of work.

3.2 Habitat Characterization

Habitat parameters recorded at each site are provided in Table 3.2-1, and representative photographs are provided in Appendix A. The most common habitat feature of nearshore areas and streambanks was a

muddy slope of varying steepness, with lesser and variable amounts of sand, gravel, or cobble. Upslope, this mud transitioned into the riparian zone that was typically vegetated with trees (especially silver maple), low terrestrial herbaceous vegetation, moss, and vines, and contained varying amounts of large woody debris and detritus. The odonate surveys were typically done during periods of low flow, therefore relatively large amounts of the muddy bank were exposed and the distance from the water line to the interface between aquatic and terrestrial habitat was relatively great.

Less common nearshore habitat types included aquatic emergent vegetation and rock. Aquatic emergent vegetation was prevalent only in the more lentic habitats of Barton Cove (Site 1) and on the other side of Campground Point (Site 3). Elsewhere, aquatic emergent vegetation was either absent, or existed as a very sparse fringe of species that can tolerate daily exposure. Submerged aquatic vegetation, especially *Vallisneria*, was common in some areas but typically only as a narrow band in deeper waters.

Bare rock, an emergence substrate for odonates, is uncommon in the Connecticut River between the Deerfield River confluence and Route 116 Bridge. There are some isolated ledge outcrops, and the bridge abutments and areas near bridges often contained higher amounts of “unnatural” rock. The most “natural” rock is located in the Turners Falls bypass reach.

Table 3.1.2-1: Summary of distance traveled (height above water and distance from the edge of the water) and eclosure substrate for exuviae collected in June 2014.

	Survey Site*							
Parameter	**1**	**3**	**4**	**5****	**6**	**7**	**8**	**Total**
Sample Size	28	-	37	53	50	79	-	247
Vertical Height from Waters Surface (ft)								
Mean	1.5	-	4.1	5.1	5.4	4.1	-	4.4
Minimum	0.5	0.0	0.3	0.5	1.5	2.0	4.0	0
Maximum	3.0	3.0	7.0	9.0	8.5	8.0	8.0	9
Lateral Distance from Waters Edge (ft)								
Mean	14.0	-	13.8	17.8	5.8	7.9	-	12.7
Minimum	0.0	0.0	2.0	0.0	0.0	5.5	10.0	0
Maximum	15.0	3.0	23.0	42.0	8.0	20.0	25.0	42
Eclosure Substrate								
Aquatic Emergent Vegetation	25	X	0	0	0	0	0	25
Terrestrial Herbaceous Vegetation	0	0	23	10	18	48	X	99
Tree	0	0	4	33	0	3	X	40
Coarse Fallen Wood	3	X	3	2	1	2	X	11
Soil	0	0	6	7	31	25	X	69
Rock	0	0	1	1	0	1	X	3

*These data were not collected at Site 2.

**At least 200 more exuviae found at Site 5. Mostly 2-8 ft above water's surface and 4-7 ft from waters edge. Found mostly on low herbaceous vegetation and trees.

- Ranges and cursory descriptions were recorded at Site 3 and Site 8, thus sample size and means were not calculated.

X indicates that exuviae were found on that specific habitat type, 0 indicates that it was not. The reason X is used for Site 3 and Site 8 is because exuviae were not quantified at those two sites.

Table 3.2-1: Summary of habitat parameters recorded for each survey site.

Parameter	Survey Site							
	1	2	3	4	5	6	7	8
Aquatic Habitat								
Max Depth Surveyed (ft)	2.0	2.5	2.5	4.0	2.5	2.5	4.0	4.0
Flow Velocity[1]	None	None	None	Light to Fast	Light to Moderate	Moderate to Fast	Light to Moderate	Moderate
Substrate (%)[2]								
SILT	50	10	80	20	40	15	25	20
SAND	45	0	5	20	30	15	15	20
GRAV	0	40	5	20	20	40	25	30
COBB	5	50	10	35	10	30	35	30
BEDR	0	0	0	5	0	0	0	0
Cover[3]								
%VEG	25	<5	10	<5	<5	10	<5	10
%FPOM	50	<5	75	5	20	<5	10	<5
%CPOM	10	<5	<5	10	20	<5	20	10
Aquatic Habitat Notes	Lentic habitat with littoral zone. Emergent vegetation common.	Lentic habitat, lacking littoral vegetation at time of survey.	Lentic habitat with narrow littoral zone. Emergent vegetation sparse at time of survey.	Mostly lotic-erosional habitat with nearshore depositional areas, subject to wide fluctuations.	Slow-flowing lotic habitat, sparse submerged and emergent vegetation, mostly fine substrates and detritus.	Lotic erosional; faster flows compared to nearby areas, but still with depositional areas near shoreline.	Steep muddy banks with one gravel/cobble point bar where small stream enters.	Variable conditions; rocky under bridge, gravelly near boat ramp, silt/mud along portions of shoreline.

Notes:

1. Qualitative, based on visual observations focused on the area within 30 meters of the shoreline.
2. Approximate percent cover of each substrate type throughout the site, recognizing significant small-scale variability. GRAV = gravel, COBB = Cobble, BEDR = bedrock.
3. Approximate percent cover of elements that provide cover, including submerged or emergent vegetation (VEG), detritus and fine particulate organic matter (FPOM), and woody debris/coarse particulate organic matter (CPOM)

Table 3.2-1: Summary of habitat parameters recorded for each survey site (continued).

Parameter	Survey Site 1	2	3	4	5	6	7	8
Riparian/Upland Habitat								
Bank Slope[4]	Very Gradual	Gradual	Moderate	Moderate to Vertical	Gradual to Moderate	Moderate to Steep	Moderate to Steep	Moderate to Steep
Bank Height[5]	-	2.0-3.0 ft	2.0-3.0 ft	Variable; to 10 ft	Variable; to 10 ft	Variable; to 12 ft	Variable; to 12 ft	Variable; to 15 ft
Bank Stability[6]	1	1	1	1-2	1	2-3	1-2	1-3
Land Use/Cover	Forest, Road	Forest	Forest	Forest	Forest, Cropland, Residential	Cropland, Forest, Residential	Cropland, Forest	Forest, Residential, Road
Riparian / Upland Habitat Notes	-	-	-	Some gradually sloping banks with floodplain forest upland, some steep bedrock outcrops and vertical rocky banks.	Mud/sand streambanks with overhanging silver maple. Agricultural land beyond narrow riparian buffer.	Riparian strip pf herbaceous and shrub species plus floodplain tree species. Some degree of bank instability.	Herbaceous lower bank, with silver maple floodplain forest higher. A lot of large woody debris.	Boat launch, bridge abutments, and upland development characterize this area.

Notes:

4. Qualitative. Biologists took representative photographs (Appendix A) to document nearshore and riparian habitats.
5. Qualitative. In practice, bank height was variable and difficult to measure, especially where there was a gradual transition from exposed riverbed to the toe and top of the bank. Photographs are likely more informative than these simple descriptors.
6. Informal, qualitative scoring: 1 = Stable, 2 = Moderately Stable, 3 = Moderately Unstable, 4 = Unstable

4 NEXT STEPS

4.1 Review Existing Information

Information on the odonate assemblage in the project-affected reaches of the Connecticut River will be gathered from publications, reports, and relevant case studies. Experts who were involved with the dragonfly studies in the Turners Falls Impoundment in the 2000s have been contacted to provide expert opinion and in some cases unpublished data. The life history and ecology, and particularly emergence and eclosure behavior, of these species and species groups will be summarized in the final report.

4.2 Quantitative Emergence and Eclosure Surveys

Prior to the 2015 quantitative fieldwork, another scientific collection permit will be obtained from the Massachusetts NHESP.

FirstLight proposes to conduct quantitative surveys at three sites, including one in the Turners Falls Impoundment, one in the Turner Falls bypass reach near Rock Dam, and one in in the Connecticut River below Cabot Station. The Revised Study Plan specified that the quantitative surveys would be conducted at four reaches. However, upon review of odonate data collected from 2001 to 2010 in the Turners Falls Impoundment, FirstLight believes that these studies provided ample data to meet the study objectives for all areas except Barton Cove, which was underrepresented in those studies. FirstLight will consult with NHESP on site locations but proposes the following three sites based on habitat diversity and accessibility: (1) Barton Cove/Campground Point, (2) Site 4 (Rock Dam) from this interim report, and (3) Site 8 (Route 116 Bridge) from this interim report.

Larvae may exit the water on a limited number of surfaces, such as emergent aquatic vegetation, sloped banks comprised of fine to coarse soils (e.g., mud, sand, gravel, cobble), or large rock (natural boulder or ledges, or unnatural riprap). Some larvae will stop to eclose on these surfaces, or travel farther upslope to eclose on herbaceous terrestrial vegetation, tree roots, or tree trunks. FirstLight proposes to establish transects perpendicular to the river that span the entire continuum from the water's edge into the upland terrestrial vegetation, and then determine where different species eclose along that continuum. Transects will be monumented with PVC pipe or rebar along their length. Each transect will be three meters wide, and will extend upslope from the water's edge approximately 12 meters. FirstLight has proposed increasing the transect width from what was proposed in the Revised Study Plan from 2 to 3 meters, or from $24m^2$ to $36m^2$, to increase the number of microhabitats and exuviae that occur within transects. Based on 2014 observations, it is likely that more than 100 (and possibly 300-500) exuviae will be collected per transect, per visit, during periods of peak emergence.

FERC's SPDL stated that the survey effort should be stratified in each reach to provide adequate replication of each habitat type (natural vegetation, gradually sloping mud/sand, and rock). Based on habitat characterization in 2014, some habitat types stated as being important in the SPDL were uncommon and it may not be necessary to sample these to accomplish overall objectives of this study. For example, emergent aquatic vegetation is very sparse in both the bypass reach and below Cabot Station. Barton Cove and Campground Point contain significant amounts of emergent aquatic vegetation along with other emergence habitats. More than 95 percent of the shoreline of the Connecticut River between the Deerfield River confluence and Route 116 Bridge is comprised of muddy/sandy slopes with low and variable amounts of embedded gravel and cobble, transitioning to roots and trunks of floodplain trees (especially silver maple), terrestrial herbaceous vegetation, and vines. This type of habitat is also prevalent in the bypass reach, although natural ledge outcroppings and cobble shorelines are more common. Based on habitat availability at each of the proposed survey sites, and the fact that every transect spans a continuum from the water's edge into adjacent uplands as far as odonates have been

documented to travel, FirstLight contends that the following replication (3 sites, 26 transects) is adequate to meet the objectives of the survey:

- Site 1 (Barton Cove/Campground Point): 9 transects (3 starting in emergent aquatic vegetation, 3 starting in ledge outcrop, and 3 starting in mud/sand/gravel).
- Site 2 (Site 4 from this interim report): 9 transects (3 starting in ledge outcrop, 3 starting in gravel/cobble, 3 starting in mud/sand) [there is no emergent aquatic vegetation at this site]
- Site 3 (Site 8 from this interim report): 8 transects (4 starting in gravel/cobble, 4 starting in mud/sand) [there is no ledge outcrop or emergent aquatic vegetation at this site]

The SPDL recommended a minimum of six 2-meter transects in each available habitat type (natural vegetation, gradual sloping mud/sand banks, and rock substrate) in each study reach. This effort could yield up to a potential of 72 2-meter transects per survey date or approximately 475 feet of the river bank. Our proposal would result in three to four transects per site (26 transects total), each transect being 3 meters wide. This proposed effort would survey approximately 256 feet of the river bank.

The following habitat data will be collected at each transect: GPS location of both ends, slope, elevation of the upslope and water ends, elevation of the mean high water mark, types and percent cover of each substrate type, substrate embeddedness, species composition and percent cover of aquatic and upland plants, and anything else noteworthy about conditions at each transect. All transects will be photo-documented.

Surveys for emerging larvae, exuviae, and tenerals will be conducted at each transect every two weeks from mid-May through late August, and will be timed to coincide with weather (warm air temperatures, dry and sunny days) and flow conditions (average to below-average flows, based on USGS streamflow data at the Montague City gage (01170500)) that are conducive to emergence, and during times that are generally considered peak emergence periods for target species that occur in these areas. Surveys will be conducted on weekday mornings when recreational use of the river is low. If possible, surveys will be coordinated with upstream hydropower operations to occur during a period of stable water levels to increase likelihood of collecting data on species that emerge very near the water line and might otherwise be washed away by daily flow fluctuations, and for similar reasons, will not be conducted within two days of heavy rainfall that might dislodge and wash away exuviae.

The time of day, weather, water level, and a qualitative assessment of boat traffic will be recorded at the time of each survey. For each exuvia and teneral, the vertical height above the water's surface, the horizontal distance from the water's edge, and its eclosure structure/substrate will be recorded. Each exuvia will be collected, stored in individual vials, labeled with site information and date, and preserved for later species identification.

4.3 Emergence and Eclosure Speed

Emerging larvae will be watched/tracked as they progress upslope, and the time it takes for them to stop, eclose, and fly away will be recorded. This is a time-intensive observation process that relies on seeing larvae before they stop and begin to eclose. Based on cursory observations in 2014 and discussions with other experts who have attempted these types of observations, it is feasible to accomplish this task for relatively common species (e.g., *G. vastus*, *N. yamaskanensis*, *S. spiniceps*, *M. illinoiensis*, *O. rupinsulensis*, *E. princeps*). However, it may not be possible to observe some rare species that may be outnumbered by common species by at least 1000:1 (e.g., *G. fraternus*, *G. ventricosus*, *G. abbreviatus*, *S. amnicola*). FirstLight concurs with FERCs SPDL that stated, "*We recommend FirstLight record a minimum of 10 observations per species or species group, provided that 10 individuals from each group are encountered during the emergence surveys*."

Observations will coincide with the quantitative exuvia surveys. Biologists will look for larvae exiting the water or crawling on land, and will focus on single individuals as they crawl upslope and come to rest to begin the eclosure process. The most critical period is the time from when larvae begin to eclose and when the teneral's wings have hardened and the adult flies away. Biologists will use a stopwatch to record the duration of this process, and photograph the teneral to help verify species-level identification. For each exuvia, the vertical height above the water's surface, the horizontal distance from the water's edge, and its eclosure structure/substrate will be recorded. Each exuvia will be collected, stored in individual vials, labeled with site information and date, and identified to species in the laboratory.

4.4 Water Fluctuation Impact Assessment

FirstLight will deploy a water level logger (with the capability to record temperature) set to record data at 15-minute intervals in each quantitative survey reach to accurately evaluate water levels, standardize field measurements, and describe temperature in relation to odonate emergence behavior. The loggers will be installed approximately mid-May, and remain in place for the duration of the survey.

In addition, hydraulic models, that have been developed for the whole study area independent of the odonate study, will be used to determine if water level fluctuations affect the emergence and eclosure success of state-listed odonates. The timing (i.e., when species emerge), distance travelled (both horizontal and vertical), and duration (i.e., speed) of eclosure for species and/or species groups will be used in concert with the hydraulic model to determine if, how, and when they are most vulnerable to fluctuating water levels.

APPENDIX A – PHOTOGRAPHS

Site 1: Barton's Cove

Site 1: Barton's Cove

Site 2: Barton's Cove

Site 2: Barton's Cove

Site 3: Campground Point

Site 3: Campground Point

Site 4: Bypass Reach

Site 4: Bypass Reach

Site 4: Bypass Reach

Site 4: Bypass Reach

Site 4: Bypass Reach

Site 5: Downstream of RR Bridge

Site 5: Downstream of RR Bridge

Site 6: Between RR Bridge and Third Island

Site 6: Between RR Bridge and Third Island

Site 7: Near Third Island

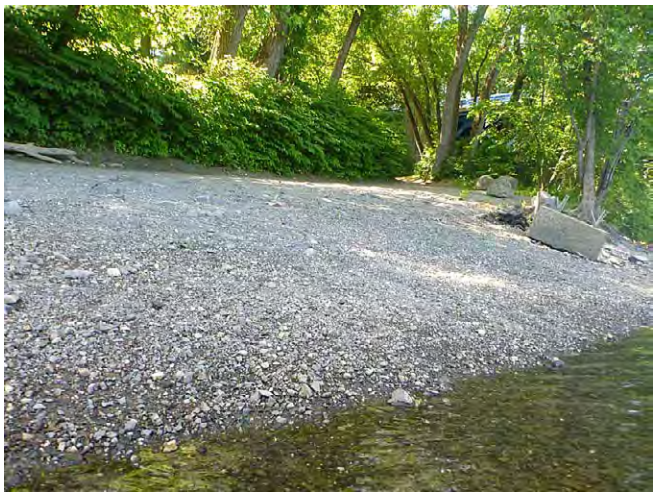
Site 7: Near Third Island

Site 7: Near Third Island

Site 7: Near Third Island

Site 8: Near Route 116 Bridge

Site 8: Near Route 116 Bridge



Site 8: Near Route 116 Bridge

APPENDIX B:
PHASE 2 (2015) FIELD SAMPLING PLAN

From: Ethan Nedeau <ethan@biodrawversity.com>
Sent: Tuesday, May 12, 2015 10:36 AM
To: Hazelton, Peter (FWE)
Cc: Jason George
Subject: 2015 Odonate Field Study
Attachments: 2015 Odonate Field Study.docx

Hi Pete,
Just sending this updated field sampling plan for the odonate study. We intend to set up transects this week and check for any early emergence. We'll begin sampling next week if we need to, but we are hoping emergence holds off for another week. These warmer temperatures might be quickening things.

-Ethan

--
**New Address
Ethan Nedeau, Biodrawversity LLC
206 Pratt Corner Road, Leverett, MA 01054
Cell: (413) 253-6561 / Email: nedeau.ethan@gmail.com
Website: www.biodrawversity.com

2015 Odonate Field Study

1. Quantitative Emergence and Eclosure Surveys

FirstLight will conduct quantitative surveys at five sites in the Connecticut River. Concurrence on these five sites was reached during an April 28, 2015 meeting with NHESP. Precise locations of transects within these sites will be determined in the field.

1. Barton's Cove/Campground Point (Gill)
2. Downstream from the Rock Dam in the bypass reach (Montague)
3. Area from bike path bridge to Montague City Road, opposite the Deerfield River confluence (Montague)
4. DFW conservation lands on the eastern shore upstream from the Sawmill River confluence (Montague)
5. Eastern shore near the Route 116 Bridge (Sunderland)

At each site, FirstLight will establish six transects that are oriented perpendicular to the river that span the continuum from the water's edge into the upland terrestrial vegetation. Each transect will be three meters wide, and will extend upslope from the water's edge approximately 12 meters. Transects will be monumented with PVC pipe or rebar along their length. The benchmark elevations will be surveyed and geo-referenced with GPS, and benchmarked to Project (NGVD29) datum using a Real-Time Kinematic-Global Positioning System (RTK-GPS) unit.

Within and among the five sites, transects will be established to provide adequate representation of available habitat type (such as natural vegetation, gradually sloping mud/sand, and rock) and of varying bank slopes (i.e., steep versus shallow).

The following habitat data will be collected for each transect: GPS location of both ends, slope, elevation of the upslope and water ends, elevation of the mean high water mark, types and percent cover of each substrate type, substrate embeddedness, species composition and percent cover of aquatic and upland plants, and anything else noteworthy about conditions at each transect. All transects will be photo-documented.

Surveys for emerging larvae, exuviae, and tenerals will be conducted at each transect every two weeks according to this tentative schedule:

- May 25-29
- June 8-12
- June 22-26
- July 6-10
- July 20-24
- August 3-7
- August 17-21
- August 31-September 4

Adjustments to this schedule may be necessary depending on weather and flow conditions; for example, it might begin a week earlier if emergence begins early. Surveys will be timed to coincide with weather (warm air temperatures, dry and sunny days) and flow conditions (average to below-average flows, based on USGS streamflow data at the Montague City gage (01170500)) that are conducive to emergence. If possible, surveys will be coordinated with upstream hydropower operations to occur

during a period of stable water levels to increase likelihood of collecting data on species that emerge very near the water line and might otherwise be washed away by daily flow fluctuations, and for similar reasons, will not be conducted within two days of heavy rainfall that might dislodge and wash away exuviae.

The time of day, weather, water level, and a qualitative assessment of boat traffic will be recorded at the time of each survey. For each exuvia and teneral, the vertical height above the water's surface, the horizontal distance from the water's edge, and its eclosure structure/substrate will be recorded. Each exuvia will be collected, stored in individual vials, labeled with site information and date, and preserved for later species identification.

2. Emergence and Eclosure Speed

Emerging larvae will be watched/tracked as they progress upslope, and the time it takes for them to stop, eclose, and fly away will be recorded.

Based on cursory observations in 2014 and discussions with other experts who have attempted these types of observations, it is feasible to accomplish this task for relatively common species (e.g., *G. vastus*, *N. yamaskanensis*, *S. spiniceps*, *M. illinoiensis*, *O. rupinsulensis*, *E. princeps*). However, it may not be possible to observe some rare species that may be outnumbered by common species by at least 1000:1 (e.g., *G. fraternus*, *G. ventricosus*, *G. abbreviatus*, *S. amnicola*).

In terms of replication, biologists will record emergence/eclosure speed for no more than 20 individuals of each species per site, and will try to focus on finding uncommon species (aiming for a minimum of 10 observations for each species). The main point of this is to avoid over-replicating observations for very common species, and to achieve at least some replication for uncommon species.

Observations will coincide with the quantitative exuvia surveys. Biologists will look for larvae exiting the water or crawling on land, and will focus on single individuals as they crawl upslope and come to rest to begin the eclosure process. The most critical period is the time from when larvae begin to eclose and when the teneral's wings have hardened and the adult flies away. Biologists will use a stopwatch to record the duration of this process.

For each exuvia, the vertical height above the water's surface, the horizontal distance from the water's edge, and its eclosure structure/substrate will be recorded. Each exuvia will be collected, stored in individual vials, labeled with site information and date, and identified to species in the laboratory. Up to 10 teneral/exuvia pairs, per species, will be collected for identification purposes.

3. Water Fluctuation Impact Assessment

A hydraulic model, which will be developed for the whole study area independent of the odonate study, will be used to determine if water level fluctuations affect the emergence and eclosure success of state-listed odonates. The timing (i.e., when species emerge), distance travelled (both horizontal and vertical), and duration (i.e., speed) of eclosure for species and/or species groups will be used in concert with the hydraulic model to determine if, how, and when they are most vulnerable to fluctuating water levels.

From: Grader, Melissa <melissa_grader@fws.gov>
Sent: Wednesday, May 13, 2015 10:30 AM
To: Leddick, Jesse (FWE)
Cc: Hazelton, Peter (FWE); Nedeau, Ethan; Jason George
Subject: Re: 2015 Odonate Field Study

Neither do I.

Melissa Grader
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service - New England Field Office
103 East Plumtree Road
Sunderland, MA 01375
413-548-8002 x124
melissa_grader@fws.gov
~~~~~~
"Heaven is under our feet as well as over our heads" Henry David Thoreau

On Wed, May 13, 2015 at 10:21 AM, Leddick, Jesse (FWE) <jesse.leddick@state.ma.us> wrote:

> I don't have any additional comments, thanks.
>
> ... Jesse
> ---
> Jesse Leddick
> Endangered Species Review Biologist
> Natural Heritage & Endangered Species Program
> Massachusetts Division of Fisheries & Wildlife
> 1 Rabbit Hill Road, Westborough, MA, 01581
> Phone: 508-389-6386 | Fax: 508-389-7890
> www.mass.gov/masswildlife
>
> -----Original Message-----
> From: Hazelton, Peter (FWE)
> Sent: Tuesday, May 12, 2015 11:56 AM
> To: ethan@biodrawversity.com
> Cc: Leddick, Jesse (FWE); Grader, Melissa; jgeorge@gomezandsullivan.com
> Subject: FW: 2015 Odonate Field Study
>
> Ethan,
>
> The updated study design covers what we discussed at the meeting. The only thing I would request is to include a schedule for reporting data and delivering a report of field study to FERC.
>
> If Jesse and Melissa have no further comments, I think this study plan will accomplish the objectives of the
~~~~~~

Odonate study.

On a side note, I was out in the valley yesterday on an unrelated project and wanted to check out the access at the DFW CT River Access Site. Unfortunately I ran out of time and had to return east. Did you scope out the site? Is there anything else you need from me to help with access?

Pete

From: Ethan Nedeau [ethan@biodrawversity.com]
Sent: Tuesday, May 12, 2015 10:35 AM
To: Hazelton, Peter (FWE)
Cc: Jason George
Subject: 2015 Odonate Field Study

Hi Pete,
Just sending this updated field sampling plan for the odonate study. We intend to set up transects this week and check for any early emergence. We'll begin sampling next week if we need to, but we are hoping emergence holds off for another week. These warmer temperatures might be quickening things.

-Ethan

--
**New Address
Ethan Nedeau, Biodrawversity LLC
206 Pratt Corner Road, Leverett, MA 01054
Cell: (413) 253-6561 / Email: nedeau.ethan@gmail.com<mailto:nedeau.ethan@gmail.com>
Website: www.biodrawversity.com<http://www.biodrawversity.com>

Commonwealth of Massachusetts

Division of Fisheries & Wildlife

Jack Buckley, Director

Scientific Collection Permit

INVERTEBRATES

VALID

2015

BIODRAWVERSITY LLC
ETHAN NEDEAU
206 PRATT CORNER ROAD
LEVERETT, MA 01054

DATE: 6/18/2015
PERMIT# : 589.15WI
NHESP Tracking # : 11-30121

Subpermitee(s): CORBIN BRODY, MATTHEW SMITH

is (are) hereby authorized, in accordance with the provisions of Section 4, Chapter 131 and 131A of the Massachusetts General Laws, to remove from the wild within the Commonwealth, subject to conditions set forth below, the following species and numbers:

MAY HAND CAPTURE ALL SPECIES OF FRESHWATER MUSSELS AND ODONATES AS PART OF QUALITATIVE SURVEY. MUST FOLLOW THE NHESP ENDANGERED SPECIES SURVEY GUIDELINES FOR FRESHWATER MUSSELS AND APPROVED SCOPE OF WORK SUBMITTED WITH PERMIT APPLICATION. NHESP SPECIES OBSERVATION FORMS MUST BE SUBMITTED FOR ALL STATE-LISTED RARE SPECIES ENCOUNTERED. WITHIN 10 DAYS OF THE FIRST OBSERVATION OF A GIVEN STATE-LISTED SPECIES, A NHESP SPECIES OBSERVATION FORM MUST BE SUBMITTED TO THE NHESP. ALL OTHER NHESP OBSERVATION FORMS REPORTING SUBSEQUENT OBSERVATIONS OF A GIVEN SPECIES SHALL BE SUBMITTED BY DECEMBER 31.

The following method(s) of taking is (are) hereby authorized:

HAND CAPTURE, D-NETS OR OTHER APPROPRIATE NETS

Collection activites under this permit shall be restricted to the following locations, subject to the approval of private landowners

CONNECTICUT RIVER IN GILL, MONTAGUE AND SUNDERLAND, MA

All specimens secured under this permit shall be donated to the following institutions:

ALL LIVE SPECIMENS SHALL BE RELEASED. A REPRESENTATIVE COLLECTION OF SPENT SHELLS MAY BE COLLECTED AND SUBMITTED AS VOUCHER SPECIMEN TO NHESP WITH RAOFS; OTHERS MAY BE DONATED TO A UNIVERSITY OR RESEARCH INSTITUTION.

No specimen taken under the authority of this permit may be sold. No specimen may be transferred to another not duly licensed.

This permit of a copy thereof shall be carried at all times by the permittee and subpermittee(s) while engaged in the activities authorized herein.

This permit does not absolve the permittee from compliance in full with any and all other applicable federal, state and local requirements, including the acquisition of a federal endangered species permit if required.

Upon expiration of this permit, a complete report detailing all collection activities shall be filed with this office and must include a listing of all species taken, numbers of specimens, and the disposition of same.

This permit, unless sooner revoked for cause, shall expire on December 31 of the year of issue.

Jack Buckley

_____

Jack Buckley, Director

Division of Fisheries and Wildlife *www.mass.gov/masswildlife*
Field Headquarters, One Rabbit Hill Road, Westborough, MA 01581 (508) 389-6300 Fax (508) 389-7890
An Agency of the Department of Fish and Game

APPENDIX C:
2015 AND 2016 SITE PHOTOS

Site 2015-1 (Route 116 Bridge). Transect 1.

Site 2015-1 (Route 116 Bridge). Transect 2.

Site 2015-1 (Route 116 Bridge). Transect 3.

Site 2015-1 (Route 116 Bridge). Transect 4.

Site 2015-1 (Route 116 Bridge). Transect 5.

Site 2015-1 (Route 116 Bridge). Transect 6.

Site 2015-2 (MADFW Lands). Transect 1.

Site 2015-2 (MADFW Lands). Transect 2.

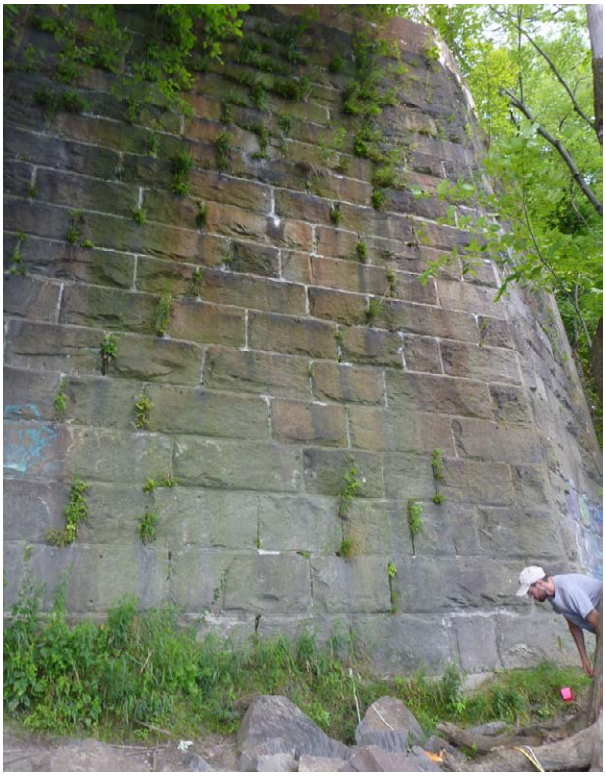
Site 2015-2 (MADFW Lands). Transect 3.

Site 2015-2 (MADFW Lands). Transect 4.

Site 2015-2 (MADFW Lands). Transect 5.

Site 2015-2 (MADFW Lands). Transect 6.

Site 2015-3 (Poplar Street). Transect 1.

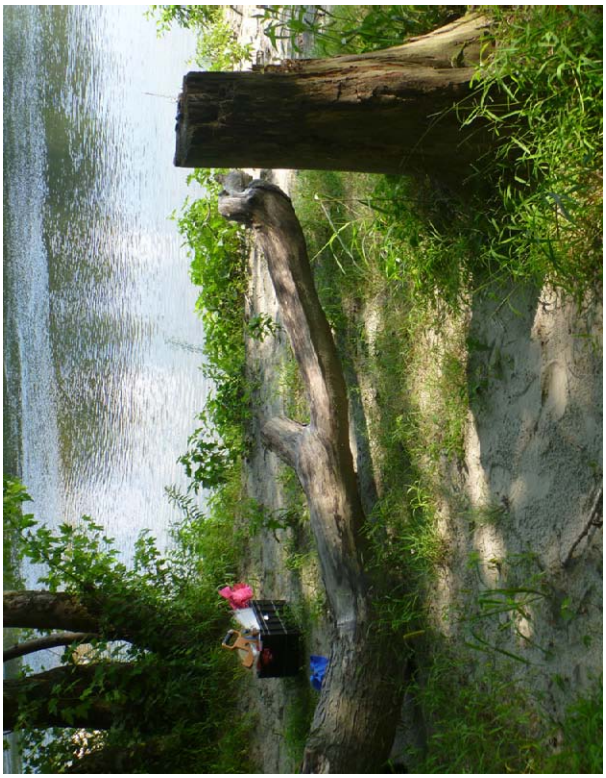


Site 2015-3 (Poplar Street). Transect 2.

Site 2015-3 (Poplar Street). Transect 3.

Site 2015-3 (Poplar Street). Transect 4.

Site 2015-3 (Poplar Street). Transect 5.



Site 2015-3 (Poplar Street). Transect 6.

Site 2015-4 (Rock Dam). Transect 1.

Site 2015-4 (Rock Dam). Transect 2.

Site 2015-4 (Rock Dam). Transect 3.

Site 2015-4 (Rock Dam). Transect 4.

Site 2015-4 (Rock Dam). Transect 5.

Site 2015-4 (Rock Dam). Transect 6.

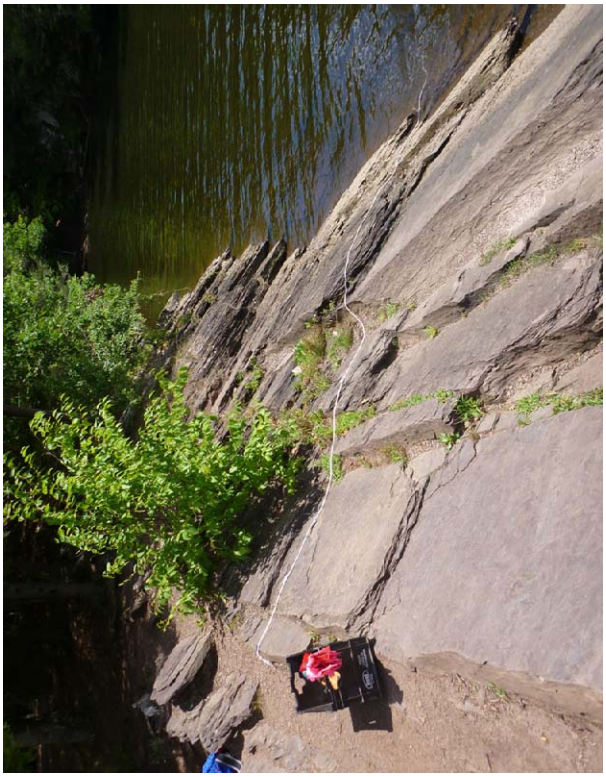
Site 2015-5 (Barton Cove). Transect 1.

Site 2015-5 (Barton Cove). Transect 2.

Site 2015-5 (Barton Cove). Transect 3.

Site 2015-5 (Barton Cove). Transect 4.

Site 2015-5 (Barton Cove). Transect 1.



Site 2015-5 (Barton Cove). Transect 2.

Site 2016-2 (Hatfield Boat Ramp)

Site 2016-3 (Route 116 Bridge, West Side)

Site 2016-4 (Route 116 Bridge, East Side)

Site 2016-5 (DFW Conservation Land, Montague)

Site 2016-8 (Mt. Hermon School)

APPENDIX D:
PHASE 3 (2016) FIELD SAMPLING PLAN AND CORRESPONDENCE RECORDS

FirstLight Turners Falls/Northfield Mountain Relicensing
Odonate Study
2016 Field Sampling Plan, Revision 1
May 20, 2016

In 2016, biologists will focus on obtaining additional emergence and eclosure data, especially for state-listed odonate species and other species underrepresented in 2015. NHESP specifically asked for additional information on *Neurocordulia yamaskenensis*, *Stylurus amnicola*, *Gomphus ventricosus*, *Gomphus vastus*, *Gomphus abbreviatus* and *Gomphus fraternus*. Additionally, observations of *Stylurus spiniceps* may be used to supplement *Stylurus amnicola* if not enough observations are possible.

Survey Locations: FirstLight will consult with NHESP about the best locations for these surveys. Locations may include one or more of the five areas sampled in 2015, or other locations where historic data suggest that there is a greater likelihood of encountering rare species. This could be either upstream in the Turners Falls impoundment, alternate sites from Sunderland Bridge to the Turners Falls Dam, or in Reach 5 (i.e., downstream of Sunderland Bridge to Holyoke Dam).

Survey Timing: Surveys for emerging larvae, exuviae, and tenerals will be conducted during peak emergence of target species, which is usually sometime from late May to early July. Flow, weather conditions, and odonate emergence will be monitored starting in mid-May to ensure that we do not miss any important emergence events. Surveys will be timed to coincide with weather (warm air temperatures, dry and sunny days) and flow conditions (average to below-average flows, based on USGS streamflow data at the Montague City gage (01170500)).

Methods: Biologists will look for larvae exiting the water or crawling on land, and will focus on single individuals as they crawl upslope and come to rest to begin the eclosure process. The most critical period is the time from when larvae begin to eclose and when the teneral's wings have hardened and the adult flies away. Biologists will record the time it takes for them to stop, eclose, and fly away.

The minimum survey effort for each site would be two biologists for one day, with the day starting ~5:00-6:00 am and ending by ~3:00, or approximately 20-person hours per site. More time may be added for certain sites, and certain times of day, to try to obtain sufficient data for each of the target species. The key limiting factor is that the first half of each day is a critical time period, and therefore a pair of biologists can survey only one site per day. We propose to have two teams during the late May/early June sampling period when most of the *Gomphus* sp. are emerging and more sites need to be surveyed, and will likely just use a single team in late June/early July when the surveys are primarily targeting *Stylurus amnicola*. As recommended by NHESP, the list of survey sites is provided in Table 1 below.

In terms of replication, biologists will record emergence/eclosure speed for up to 20 individuals of each species, with primary focus on state-listed species (aiming for a minimum of 10 observations for each state-listed species). For each exuvia, the vertical height above the water's surface, the horizontal distance from the water's edge, its eclosure structure/substrate, and the time it was observed will be recorded. Biologists will photograph each eclosing specimen and teneral, with a label in each photograph so the photographs can be associated with specific data collected for each specimen.

After eclosure is complete, each exuvia will be collected, stored in individual vials, labeled with site information and date, and identified to species in the laboratory. All survey sites will be photo-documented. The water level, time of day, and weather (sunlight, wind speed, air temperature, humidity) will be recorded at the time of each survey.

Table 1: Proposed Odonate Survey Sites for 2016.

Site	Latitude	Longitude	Reason	Note
Gomphus fraternus Site 1	42.26523	-72.59797	Previous location of *G. fraternus* observations	Choose **one** of these sites. Both sites on Eastern Bank
Gomphus fraternus Site 2	42.4768	-72.57579	Previous location of *G. fraternus* observations	
2015 Site 2 (DFW lands)	42.52961	-72.56740	High numbers of rares in 2015 study	This site should be surveyed again. Use same site as 2015.
2015 Site 4 (Rock Dam)	42.59519	-72.57898	Highest numbers of *G. abbreviatus* in 2015	This site should be surveyed again. Use same site as 2015.
Bathory/Gallagher Site (TFI)	42.62186	-72.48377	High numbers of rares in NEE, Inc. studies	This site should be surveyed. Site is on Western Bank.
2008 NEE, Inc. Site 4 (TFI)	42.66407	-72.46974	High numbers of rares in NEE, Inc. studies	This site should be surveyed. Site is on Eastern Bank.

Note: Sites provided by J. Leddick (MA NHESP) via email on May 13, 2016.

From: Hazelton, Peter (FWE) <Peter.Hazelton@MassMail.State.MA.US>
Sent: Monday, May 23, 2016 1:51 PM
To: Jason George; Leddick, Jesse (FWE); Mark Wamser
Cc: Nedeau, Ethan; Donohue, James; Stira, Robert
Subject: RE: FirstLight Odonate Study - 2016 Field Sampling Proposal

Jason,

Thanks for putting this together. This appears to have covered all of our comments and concerns brought up during the recent conference call.

Best of luck to Ethan and his crew in getting the final bugs! At least the weather has been cooperating this far.

Pete

From: Jason George [mailto:jgeorge@gomezandsullivan.com]
Sent: Friday, May 20, 2016 10:45 AM
To: Leddick, Jesse (FWE); Mark Wamser; Hazelton, Peter (FWE)
Cc: Nedeau, Ethan; Donohue, James; Stira, Robert
Subject: RE: FirstLight Odonate Study - 2016 Field Sampling Proposal

Hi Jesse and Pete,

We have addressed your comments in the attached field sampling plan for the 2016 odonate surveys at the Turners Falls Project. Ethan scouted the sites yesterday and reported that no emergence activity was detected thus far. He'll continue checking and begin the surveys according to the plan.

Please copy the group with any additional comments. Thank you.

Jason George
Environmental Scientist
Gomez and Sullivan Engineers, DPC
PO Box 2179
Henniker, NH 03242
Office: (603) 428-4960
Cell: (603) 340-7666
jgeorge@gomezandsullivan.com

GOMEZ AND SULLIVAN ENGINEERS

From: Leddick, Jesse (FWE) [mailto:Jesse.Leddick@MassMail.State.MA.US]
Sent: Friday, May 13, 2016 8:06 AM
To: Mark Wamser <mwamser@gomezandsullivan.com>; Jason George <jgeorge@gomezandsullivan.com>; Hazelton, Peter (FWE) <peter.hazelton@state.ma.us>
Cc: Nedeau, Ethan <ethan@biodrawversity.com>; Donohue, James <james.donohue@na.engie.com>
Subject: RE: FirstLight Odonate Study - 2016 Field Sampling Proposal

Mark, Jason, and Ethan,

We reviewed the field sampling proposal and provided a few comments, attached. We understand and are comfortable with FirstLight's proposal **not** to install water level loggers as part of this follow up work.

Based on a comparison of data collected across various studies, we would recommend that surveys occur at the sites outlined below. Four (4) of these represent new sites, so we have attached locus maps and additional information on each below. We understand that the *G. fraternus* Site 1 is located in Reach 5, but are not requesting assessment of operations effects, etc. outside of the previously established study area.

Site	Latitude	Longitude	Reason	Note
Gomphus fraternus Site 1	42.26523	-72.59797	Previous location of *G. fraternus* observations	Choose **one** of these sites. Both sites on Eastern Bank
Gomphus fraternus Site 2	42.4768	-72.57579	Previous location of *G. fraternus* observations	
2015 Site 2 (DFW lands)	42.52961	-72.56740	High numbers of rares in 2015 study	This site should be surveyed again. Use same site as 2015.
2015 Site 4 (Rock Dam)	42.59519	-72.57898	Highest numbers of *G. abbreviatus* in 2015	This site should be surveyed again. Use same site as 2015.
Bathory/Gallagher Site	42.62186	-72.48377	High numbers of rares in NEE, Inc. studies	This site should be surveyed. Site is on Western Bank.
2008 NEE, Inc. Site 4	42.66407	-72.46974	High numbers of rares in NEE, Inc. studies	This site should be surveyed. Site is on Eastern Bank.

If you have any questions about the new, recommended field sites, or want to discuss the sampling proposal further for any reason, please contact me or Pete. Thanks again for everyone's work on this.

.... Jesse

Jesse Leddick
Natural Heritage & Endangered Species Program
Massachusetts Division of Fisheries & Wildlife
1 Rabbit Hill Road, Westborough, MA, 01581
Phone: 508-389-6386 | Fax: 508-389-7890
www.mass.gov/masswildlife

From: Mark Wamser [mailto:mwamser@gomezandsullivan.com]
Sent: Wednesday, May 11, 2016 3:09 PM
To: Leddick, Jesse (FWE); Jason George; Hazelton, Peter (FWE)
Cc: Nedeau, Ethan; Donohue, James
Subject: RE: FirstLight Odonate Study - 2016 Field Sampling Proposal

Jesse- I want to close the loop relative to the water level loggers. As stated on the call, and as discussed internally after the call, we are not proposing to install water level loggers as part of this follow up work. Thanks Mark

Mark Wamser, PE
Senior Water Resource Engineer
Gomez and Sullivan Engineers, DPC
41 Liberty Hill Road
PO Box 2179
Henniker, NH 03242
P 603-428-4960
C 603-568-6088
F 603-428-3973

GOMEZ AND SULLIVAN ENGINEERS

From: Leddick, Jesse (FWE) [mailto:Jesse.Leddick@MassMail.State.MA.US]
Sent: Wednesday, May 11, 2016 3:03 PM
To: Jason George <jgeorge@gomezandsullivan.com>; Hazelton, Peter (FWE) <peter.hazelton@state.ma.us>
Cc: Nedeau, Ethan <ethan@biodrawversity.com>; Mark Wamser <mwamser@gomezandsullivan.com>; Donohue, James <james.donohue@na.engie.com>
Subject: RE: FirstLight Odonate Study - 2016 Field Sampling Proposal

Thanks, Jason. We will review and provide comments – and more information on recommended survey sites - ASAP. All the best,

.... Jesse

Jesse Leddick
Natural Heritage & Endangered Species Program
Massachusetts Division of Fisheries & Wildlife
1 Rabbit Hill Road, Westborough, MA, 01581
Phone: 508-389-6386 | Fax: 508-389-7890
www.mass.gov/masswildlife

From: Jason George [mailto:jgeorge@gomezandsullivan.com]
Sent: Tuesday, May 10, 2016 2:12 PM
To: Leddick, Jesse (FWE); Hazelton, Peter (FWE)
Cc: Nedeau, Ethan; Mark Wamser; Donohue, James
Subject: FirstLight Odonate Study - 2016 Field Sampling Proposal

Hi Pete and Jesse, as a follow-up to our call yesterday, attached is FirstLight's proposed sampling plan for a 2016 odonate study. This was developed based on your comments on the study report and our call yesterday.

On that call, Pete agreed to provide some recommended survey sites for target state-listed species. Please copy the group with this information as Ethan Nedeau will be leading the survey efforts again this year.

Please let us know if you have any additional questions. Thank you.

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From: Hazelton, Peter (FWE) <Peter.Hazelton@MassMail.State.MA.US>
Sent: Friday, May 27, 2016 5:27 PM
To: nedeau.ethan@gmail.com; Jason George
Cc: Leddick, Jesse (FWE)
Subject: RE: Survey sites

Ethan,

Hatfield is a bit farther downstream than the sites we were looking at from last year and previously. However, I think your assessment is correct that we need to include areas where the species are emerging (if from the sun exposure), to maximize data collection on emergence timing of the target species. So, I think this site would be a very good one to add, in lieu of one of the others (e.g. the downstream Fraternus site).

What about at the Deerfield confluence? Is there a western bank site near there that would work?

We did plan on one of the sites in the Turners falls impoundment being on the western bank, but the upper site could also be converted to the western bank as we have records from there too.

Pete

-----Original Message-----
From: nedeau.ethan@gmail.com [mailto:nedeau.ethan@gmail.com]
Sent: Friday, May 27, 2016 4:22 PM
To: Jason George; Hazelton, Peter (FWE)
Subject: Survey sites

Hi Guys,
I had a thought today that most of our survey sites happened to be on the east side of the river and wouldn't get the early morning sun and warmth that might be an important trigger for emergence. We had not detected emergence at those sites this week. I came to the Hatfield boat ramp this afternoon, where long stretches of the western shoreline are accessible, and indeed found much more emergence activity. So I would like to make an attempt to hit western shorelines generally near some of the sites we had selected. And, actually, if Pete concurs I would propose including this Hatfield boat ramp site where I can access at least a half mile of good habitat.

Thoughts?

APPENDIX E: SPECIES COUNTS FOR THE PHASE 2 (2015) QUANTITATIVE SAMPLING BY SURVEY SITE, SAMPLING PERIOD, AND TRANSECT

			Species																	
Site	Period	Trans	BaJa	BoVi	CoMa	DrSp	EpPr	GoAb	GoVa	HaBr	Lisp	Li	Mall	NeYa	OpRu	PeTe	StAm	StSp	Total Count	#Species
1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
1	1	5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
1	1	6	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	3	2
1	2	1	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	4	2
1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
1	2	4	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3	1
1	2	5	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	22	1
1	2	6	0	0	0	0	0	0	5	0	0	0	0	0	1	0	0	0	6	2
1	3	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
1	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	4	0	0	0	0	0	0	9	1	0	0	0	1	0	0	0	0	11	3
1	3	5	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	15	1
1	3	6	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	6	1
1	4	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	2	2
1	4	2	0	9	0	0	0	0	0	1	0	0	0	0	0	0	0	0	10	2
1	4	3	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	2
1	4	4	0	1	0	0	0	0	4	0	0	0	0	0	0	0	1	0	6	3
1	4	5	0	0	0	2	0	0	0	0	0	0	0	1	0	0	1	1	5	4
1	4	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
1	5	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1
1	5	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	2
1	5	3	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	2
1	5	4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1
1	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	1
1	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1
1	6	1	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	2	16	2
1	6	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	2
1	6	3	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	1	8	2
1	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
1	6	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1
1	6	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4	2
1	7	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1	7	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2
1	7	3	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4	2
1	7	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	7	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	7	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

			Species																	
Site	Period	Trans	BaJa	BoVi	CoMa	DrSp	EpPr	GoAb	GoVa	HaBr	Lisp	Li	Mall	NeYa	OpRu	PeTe	StAm	StSp	Total Count	#Species
1	8	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
1	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	8	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
1	8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	ALL	1	0	19	0	1	0	0	4	0	0	0	0	1	1	0	0	2	28	6
1	ALL	2	0	15	0	0	0	0	0	1	0	0	0	0	0	0	0	4	20	3
1	ALL	3	0	20	0	0	0	0	1	0	0	0	2	0	0	0	0	2	25	4
1	ALL	4	0	1	0	0	0	1	16	1	0	0	1	1	0	0	1	1	23	8
1	ALL	5	0	0	0	2	0	0	37	0	0	0	0	1	1	0	1	6	48	6
1	ALL	6	0	1	0	0	0	1	11	0	0	0	0	0	3	0	1	5	22	6
1	ALL	ALL	0	56	0	3	0	2	69	2	0	0	3	3	5	0	3	20	166	10
2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	1
2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	5	1
2	1	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	1
2	1	4	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	5	1
2	1	5	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	4	2
2	1	6	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
2	2	1	0	0	0	0	0	0	27	0	0	0	0	0	3	0	0	0	30	2
2	2	2	0	0	0	0	0	1	10	0	0	0	0	0	0	0	0	0	11	2
2	2	3	0	0	0	0	0	0	9	0	0	0	0	1	1	0	0	0	11	3
2	2	4	0	0	0	0	0	0	16	0	0	0	0	1	0	0	0	0	17	2
2	2	5	0	0	0	0	0	0	28	0	0	0	0	2	0	0	0	0	30	2
2	2	6	0	0	0	0	0	0	21	0	0	0	0	2	0	0	0	0	23	2
2	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	3	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
2	3	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2	3	4	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	1
2	3	5	0	0	0	0	0	0	9	0	0	0	0	1	0	0	0	0	10	2
2	3	6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2	4	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2	4	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
2	4	4	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	2	2
2	4	5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
2	4	6	0	0	0	2	0	0	1	0	0	0	0	0	0	0	1	1	5	4
2	5	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	5	6	2
2	5	2	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2	4	3
2	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
2	5	4	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	4	7	3
2	5	5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	4	2

			Species																	
Site	Period	Trans	BaJa	BoVi	CoMa	DrSp	EpPr	GoAb	GoVa	HaBr	Lisp	Li	Mall	NeYa	OpRu	PeTe	StAm	StSp	Total Count	#Species
2	5	6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	4	2
2	6	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
2	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
2	6	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
2	6	5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2	2
2	6	6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	3	2
2	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	7	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	7	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	7	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	8	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1
2	8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	ALL	1	0	2	0	1	0	0	27	0	0	0	0	0	5	0	0	5	40	5
2	ALL	2	0	1	0	2	0	1	10	0	0	0	0	1	5	0	0	3	23	7
2	ALL	3	0	0	0	1	0	0	9	0	0	0	1	1	3	0	0	3	18	6
2	ALL	4	0	0	0	2	0	0	20	1	0	0	1	1	5	0	0	4	34	7
2	ALL	5	0	0	0	0	0	3	40	0	0	0	0	3	1	0	0	4	51	5
2	ALL	6	0	0	0	4	0	0	23	0	0	0	0	2	1	0	1	6	37	6
2	ALL	ALL	0	3	0	10	0	4	129	1	0	0	2	8	20	0	1	25	203	10
3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	2	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
3	2	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
3	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	2	6	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	3	2	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	3	2
3	3	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1
3	3	4	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	3	3

			Species																	
Site	Period	Trans	BaJa	BoVi	CoMa	DrSp	EpPr	GoAb	GoVa	HaBr	Lisp	Li	Mall	NeYa	OpRu	PeTe	StAm	StSp	Total Count	#Species
3	3	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4	2	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	1	5	3
3	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	5	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	3
3	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1
3	5	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	2	2
3	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	6	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
3	6	2	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	4	2
3	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	2
3	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	6	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
3	6	6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1
3	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	7	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1
3	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	7	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	7	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	7	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
3	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	8	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	ALL	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	2	5	3
3	ALL	2	0	9	0	0	0	0	0	1	0	0	3	1	0	0	0	1	15	5
3	ALL	3	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	4	7	4
3	ALL	4	0	0	0	1	0	0	2	0	0	0	1	1	0	0	1	0	6	5
3	ALL	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
3	ALL	6	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	3	3
3	ALL	ALL	0	11	0	1	0	0	2	1	0	0	6	4	0	0	3	9	37	8
4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	3	1
4	1	3	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	3	2

			Species																	
Site	Period	Trans	BaJa	BoVi	CoMa	DrSp	EpPr	GoAb	GoVa	HaBr	Lisp	Li	Mall	NeYa	OpRu	PeTe	StAm	StSp	Total Count	#Species
4	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	5	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	4	1
4	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	2	4	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	3	2
4	2	5	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	4	1
4	2	6	0	0	0	0	0	3	6	0	0	0	0	1	0	0	0	0	10	3
4	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	3	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1
4	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	3	4	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	2	2
4	3	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
4	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	4	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
4	4	6	0	1	0	0	0	0	4	0	0	0	0	1	0	0	0	0	6	3
4	5	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	2
4	5	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1
4	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	5	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
4	5	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
4	5	6	0	1	0	0	0	0	0	0	0	0	1	2	0	0	0	0	4	3
4	6	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4	2
4	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
4	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	6	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	6	6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
4	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	7	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	7	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
4	7	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	8	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

			Species																	
Site	Period	Trans	BaJa	BoVi	CoMa	DrSp	EpPr	GoAb	GoVa	HaBr	Lisp	Li	Mall	NeYa	OpRu	PeTe	StAm	StSp	Total Count	#Species
4	8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	8	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
4	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	ALL	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	4	6	3
4	ALL	2	0	0	0	0	1	3	0	0	0	0	1	0	0	0	0	1	6	4
4	ALL	3	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	3	2
4	ALL	4	0	0	0	0	0	1	4	0	0	0	0	1	0	0	0	0	6	3
4	ALL	5	0	3	0	1	0	5	4	0	0	0	0	0	0	0	0	0	13	4
4	ALL	6	0	2	0	1	0	3	10	0	0	0	1	4	0	0	0	0	21	6
4	ALL	ALL	0	6	1	2	1	14	18	0	0	0	2	6	0	0	0	5	55	9
5	1	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3	1
5	1	2	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3	1
5	1	3	1	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	24	2
5	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1
5	2	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	1
5	2	3	1	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	7	2
5	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	2	5	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	4	2
5	2	6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1
5	3	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1
5	3	2	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	3	2
5	3	3	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	11	1
5	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	3	5	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	7	2
5	3	6	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	1
5	4	1	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	4	2
5	4	2	0	0	0	0	3	0	0	0	1	2	0	0	0	1	0	0	7	4
5	4	3	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	8	1
5	4	4	0	0	0	0	4	0	0	0	0	0	0	1	0	3	0	0	8	3
5	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	4	6	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1
5	5	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1
5	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	1
5	5	3	0	0	0	0	2	0	0	0	2	1	0	0	0	1	0	0	6	4
5	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	1
5	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	6	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	1
5	6	2	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	1

			Species																	
Site	Period	Trans	BaJa	BoVi	CoMa	DrSp	EpPr	GoAb	GoVa	HaBr	Lisp	Li	Mall	NeYa	OpRu	PeTe	StAm	StSp	Total Count	#Species
5	6	3	0	0	0	0	5	0	0	0	0	2	0	0	0	9	0	0	16	3
5	6	4	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	1
5	6	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
5	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	7	3	0	0	0	0	7	0	0	0	2	0	0	0	0	1	0	0	10	3
5	7	4	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	1
5	7	5	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	3	2
5	7	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	8	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	ALL	1	0	0	0	0	9	0	0	0	0	3	0	0	0	0	0	0	12	2
5	ALL	2	0	0	0	0	10	0	0	0	1	5	0	0	0	4	0	0	20	4
5	ALL	3	2	0	0	0	62	0	0	0	4	3	0	0	0	11	0	0	82	5
5	ALL	4	0	0	0	0	6	0	0	0	0	0	0	1	0	5	0	0	12	3
5	ALL	5	0	0	0	1	11	0	0	0	0	0	0	1	0	4	0	0	17	4
5	ALL	6	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	4	2
5	ALL	ALL	2	0	0	1	101	0	0	0	5	11	1	2	0	24	0	0	147	8

APPENDIX F: ECLOSURE DURATION, VERTICAL CRAWL HEIGHT, HORIZONTAL CRAWL DISTANCE, AND ECLOSURE SUBSTRATE FOR THOSE INDIVIDUALS FOR WHICH ALL OR PART OF THE ECLOSURE PROCESS WAS OBSERVED IN 2015 AND 2016.

Eclosure duration, vertical crawl height, horizontal crawl distance, and eclosure substrate for those individuals for which all or part of the eclosure process was observed in 2015 and 2016.

										ECLOSURE SUBSTRATE					
SPECIES	DATE	START	FREE	FLIGHT	START-FREE	FREE-FLIGHT	START-FLIGHT	VHEIGHT (FT)	HDISTANCE (FT)	SOIL	ROOT	TREE	HERB	DETR	NOTE
Boyeria vinosa	7/9/2015	14:00	14:30	15:24	0:30	0:54	1:24	1.8	1.0		X				
Dromogomphus spinosus	6/17/2016	8:30	8:40	9:25	0:10	0:45	0:55	2.8	6.9		X				
Dromogomphus spinosus	6/27/2016	11:00	11:20	11:41	0:20	0:21	0:41	2.5	14.9	X					
Dromogomphus spinosus	6/27/2016	13:52	14:05	14:46	0:13	0:41	0:54	6.8	19.4		X				
Dromogomphus spinosus	6/30/2015	9:48	10:18	11:46	0:30	1:28	1:58	2.3	5.2				X		
Dromogomphus spinosus	6/19/2015	10:18	10:48	11:45	0:30	0:57	1:27	2.7	8.7		X				
Dromogomphus spinosus	6/23/2015	13:07	13:37	14:12	0:30	0:35	1:05	4.1	11.2			X			
Gomphus abbreviatus	7/2/2015	13:47	14:17	15:03	0:30	0:46	1:16	0.4	0.3			X			
Gomphus vastus	6/2/2016	13:39	13:59	15:22	0:20	1:23	1:43	8.7	26.4		X		X		
Gomphus vastus	6/2/2016	8:56	9:07	10:41	0:11	1:34	1:45	5.6	9.2	X			X		
Gomphus vastus	6/2/2016	11:02	11:17	12:18	0:15	1:01	1:16	4.7	8.5	X	X		X		
Gomphus vastus	6/2/2016	8:48	9:00	10:02	0:12	1:02	1:14	6.7	10.5	X	X				
Gomphus vastus	6/2/2016	12:26	12:43	13:38	0:17	0:55	1:12	6.0	25.9				X		
Gomphus vastus	6/2/2016	9:51	10:05	11:04	0:14	0:59	1:13	5.9	8.4	X	X				
Gomphus vastus	6/2/2016	10:52	11:03	11:37	0:11	0:34	0:45	7.7	11.8		X				
Gomphus vastus	6/2/2016	11:23	11:39	12:31	0:16	0:52	1:08	7.5	10.7	X	X				
Gomphus vastus	6/2/2016	11:10	11:22	12:19	0:12	0:57	1:09	6.7	10.5	X			X		
Gomphus vastus	6/2/2016	12:59	13:15	14:06	0:16	0:51	1:07	6.1	22.5		X				
Gomphus vastus	6/2/2016	13:37	13:54	15:00	0:17	1:06	1:23	7.9	25.1	X	X				
Gomphus vastus	6/2/2016	13:37	13:53	14:49	0:16	0:56	1:12	8.1	25.3		X				
Gomphus vastus	6/2/2016	10:59	11:12	12:26	0:13	1:14	1:27	5.7	22.0				X		
Gomphus vastus	6/4/2016	10:50	11:05	11:39	0:15	0:34	0:49	11.6	20.7			X			
Gomphus vastus	6/4/2016	10:29	10:45	11:33	0:16	0:48	1:04	10.7	18.7			X			
Gomphus vastus	6/4/2016	8:57	9:09		0:12			6.9	17.4		X		X		Deformed
Gomphus vastus	6/4/2016	9:13	9:24	9:42	0:11	0:18	0:29	7.7	18.5	X					
Gomphus vastus	6/4/2016	9:31	9:39	10:34	0:08	0:55	1:03	8.7	19.8				X		
Gomphus vastus	6/4/2016	9:23	9:40	10:25	0:17	0:45	1:02	10.3	18.5			X			
Gomphus vastus	6/4/2016	9:05	9:19	10:01	0:14	0:42	0:56	9.6	17.9			X			
Gomphus vastus	6/4/2016	8:57	9:15	9:47	0:18	0:32	0:50	7.7	16.1			X			
Gomphus vastus	6/4/2016	8:58	9:13	9:50	0:15	0:37	0:52	8.8	17.2			X			
Gomphus vastus	6/4/2016	9:07	9:17	9:49	0:10	0:32	0:42	9.3	18.2			X			
Gomphus vastus	6/4/2016	9:08	9:25	9:52	0:17	0:27	0:44	6.1	14.4			X			
Gomphus vastus	6/4/2016	10:16	10:34	10:49	0:18	0:15	0:33	12.5	23.3			X			
Gomphus vastus	6/4/2016	9:52	10:15	10:59	0:23	0:44	1:07	6.7	15.7			X			
Gomphus vastus	6/4/2016	9:15	9:28	9:43	0:13	0:15	0:28	7.2	16.1			X			
Gomphus vastus	6/4/2016	9:32	9:43	11:08	0:11	1:25	1:36	8.4	19.7				X		
Gomphus vastus	6/4/2016	11:02	11:16	12:00	0:14	0:44	0:58	7.2	20.0		X				
Gomphus vastus	6/4/2016	10:05	10:35	11:05	0:30	0:30	1:00	5.8	17.9		X				
Gomphus vastus	6/4/2016	10:21	10:37	11:07	0:16	0:30	0:46	6.8	19.2		X				
Gomphus vastus	6/4/2016	10:38	10:52	11:08	0:14	0:16	0:30	6.6	19.0		X				
Gomphus vastus	6/6/2016	14:23	14:41	15:20	0:18	0:39	0:57	8.4	17.1	X	X	X			
Gomphus vastus	6/6/2016	14:27	14:45	15:18	0:18	0:33	0:51	8.2	14.8	X	X	X			
Gomphus vastus	6/6/2016	14:30	14:45	15:34	0:15	0:49	1:04	9.8	18.0	X					
Gomphus vastus	6/6/2016	14:30	14:39	15:34	0:09	0:55	1:04	9.0	17.4	X					
Gomphus vastus	6/6/2016	11:49	12:10	12:53	0:21	0:43	1:04	15.6	24.6			X			
Gomphus vastus	6/6/2016	14:43	14:53	15:38	0:10	0:45	0:55	7.4	14.8	X	X			X	
Gomphus vastus	6/6/2016	14:29	14:42	15:21	0:13	0:39	0:52	4.2	10.5	X	X				
Gomphus vastus	6/6/2016	13:03	13:20		0:17			1.6	5.2		X				Died
Gomphus vastus	6/6/2016	14:48	15:02		0:14			4.2	11.5	X	X				Deformed
Gomphus vastus	6/6/2016	12:43	12:58	13:39	0:15	0:41	0:56	3.8	9.5		X				
Gomphus vastus	6/6/2016	14:18	14:43	15:24	0:25	0:41	1:06	6.7	15.1	X	X				
Gomphus vastus	6/6/2016	14:26	14:41	15:27	0:15	0:46	1:01	7.5	16.4	X					
Gomphus vastus	6/6/2016	14:42	15:02	15:44	0:20	0:42	1:02	7.1	15.4	X	X				
Gomphus vastus	6/6/2016	14:12	14:33	15:02	0:21	0:29	0:50	3.2	6.9	X	X				
Gomphus vastus	6/6/2016	14:37	14:49		0:12			4.2	11.2	X	X				Deformed
Gomphus vastus	6/6/2016	9:55	10:15	10:55	0:20	0:40	1:00	1.7	5.9		X				
Gomphus vastus	6/6/2016	13:07	13:18	14:12	0:11	0:54	1:05	3.0	6.9	X					
Gomphus vastus	6/6/2016	14:48	15:06		0:18			8.1	16.7	X	X				Deformed
Gomphus vastus	6/6/2016	14:52	15:07	15:58	0:15	0:51	1:06	7.8	16.4	X	X				
Gomphus vastus	6/6/2016	13:56	14:18	14:57	0:22	0:39	1:01	2.1	5.7		X				

Gomphus vastus	6/6/2016	14:28	14:44	15:20	0:16	0:36	0:52	6.9	15.4	X	X				
Gomphus vastus	6/6/2016	14:47	15:03	15:44	0:16	0:41	0:57	6.2	11.6	X	X				
Gomphus vastus	6/6/2016	11:55	12:15	13:03	0:20	0:48	1:08	2.9	5.6		X	X			
Gomphus vastus	6/6/2016	12:24	12:37	13:27	0:13	0:50	1:03	6.3	12.5			X			
Gomphus vastus	6/6/2016	12:14	12:24	13:19	0:10	0:55	1:05	3.1	5.6		X	X			
Gomphus vastus	6/6/2016	13:45	13:59		0:14			4.4	10.8		X				Died
Gomphus vastus	6/6/2016	14:32	14:49	15:35	0:17	0:46	1:03	7.6	14.8	X	X				
Gomphus vastus	6/6/2016	12:25	12:42	13:38	0:17	0:56	1:13	2.7	8.9			X			
Gomphus vastus	6/6/2016	13:23	13:37	14:43	0:14	1:06	1:20	8.0	14.4		X				
Gomphus vastus	6/6/2016	14:49	15:04	15:42	0:15	0:38	0:53	12.0	23.0	X	X		X		
Gomphus vastus	6/6/2016	14:27	14:45		0:18			8.0	14.4		X				Died
Gomphus vastus	6/6/2016	14:04	14:22	14:56	0:18	0:34	0:52	6.0	12.8			X			
Gomphus vastus	6/6/2016	12:45	13:09	14:01	0:24	0:52	1:16	4.4	10.8		X				
Gomphus vastus	6/6/2016	14:20	14:34	15:12	0:14	0:38	0:52	3.7	6.9		X				
Gomphus vastus	6/6/2016	14:17	14:36	15:17	0:19	0:41	1:00	6.4	13.8	X	X				
Gomphus vastus	6/3/2016	8:41	9:03	9:57	0:22	0:54	1:16	6.6	7.5		X				
Gomphus vastus	6/3/2016	7:58	8:15	9:00	0:17	0:45	1:02	9.8	28.0		X				
Gomphus vastus	6/3/2016	8:00	8:20	9:00	0:20	0:40	1:00	9.8	28.3		X				
Gomphus vastus	6/4/2016	11:57	12:20	13:05	0:23	0:45	1:08	7.4	37.4	X					
Gomphus vastus	6/4/2016	11:41	12:10	12:30	0:29	0:20	0:49	7.1	37.4					X	
Gomphus vastus	6/4/2016	10:14	10:40	11:29	0:26	0:49	1:15	8.5	39.0			X			
Gomphus vastus	6/4/2016	12:18	12:38	13:08	0:20	0:30	0:50	7.1	37.4				X		
Gomphus vastus	6/4/2016	12:47	13:05	13:49	0:18	0:44	1:02	8.9	41.0					X	
Gomphus vastus	6/4/2016	12:47	13:08	13:50	0:21	0:42	1:03	8.7	38.7			X	X		
Gomphus vastus	6/4/2016	12:53	13:11	13:47	0:18	0:36	0:54	8.5	39.0				X		
Gomphus vastus	6/4/2016	11:48	12:05	12:43	0:17	0:38	0:55	7.1	36.1				X		
Gomphus vastus	6/4/2016	11:20	11:44	12:30	0:24	0:46	1:10	6.9	35.8				X		
Gomphus vastus	6/4/2016	11:22	11:44	12:32	0:22	0:48	1:10	6.7	35.8				X		
Gomphus vastus	6/4/2016	11:41	12:06	12:45	0:25	0:39	1:04	6.0	35.1	X					
Gomphus vastus	6/4/2016	10:10	10:26		0:16			5.8	35.4				X		Died
Gomphus vastus	6/4/2016	12:29	12:44	13:21	0:15	0:37	0:52	7.4	36.1		X				
Gomphus vastus	6/4/2016	12:08	12:24	12:48	0:16	0:24	0:40	7.0	38.0		X				
Gomphus vastus	6/4/2016	11:57	12:14	13:03	0:17	0:49	1:06	6.8	38.0		X				
Gomphus vastus	6/4/2016	12:58	13:24	14:09	0:26	0:45	1:11	7.5	38.4		X				
Gomphus vastus	6/4/2016	12:05	12:14	13:00	0:09	0:46	0:55	7.5	38.7		X				
Gomphus vastus	6/4/2016	12:21	12:46	13:23	0:25	0:37	1:02	10.0	43.0				X		
Gomphus vastus	6/4/2016	12:20	12:45	13:30	0:25	0:45	1:10	9.0	42.0					X	
Gomphus vastus	6/4/2016	11:35	11:55	12:40	0:20	0:45	1:05	9.1	42.0				X		
Gomphus vastus	6/4/2016	12:45	13:11	13:44	0:26	0:33	0:59	8.9	42.3					X	
Gomphus vastus	6/4/2016	13:14	13:28	14:10	0:14	0:42	0:56	9.2	42.3					X	
Gomphus vastus	6/4/2016	12:39	12:58	13:31	0:19	0:33	0:52	10.2	47.6	X					
Gomphus vastus	6/4/2016	11:15	11:43	12:18	0:28	0:35	1:03	7.2	39.7				X		
Gomphus vastus	6/4/2016	11:35	11:58	12:40	0:23	0:42	1:05	7.4	39.7		X				
Gomphus vastus	6/4/2016	10:45	11:08	11:50	0:23	0:42	1:05	7.4	39.7					X	
Gomphus vastus	6/4/2016	11:59	12:20	13:15	0:21	0:55	1:16	9.6	44.9					X	
Gomphus vastus	6/4/2016	10:20	10:40	11:25	0:20	0:45	1:05	8.7	43.0				X		
Gomphus vastus	6/4/2016	10:21	10:41	11:23	0:20	0:42	1:02	8.7	43.0				X		
Gomphus vastus	6/4/2016	10:21	10:43	11:27	0:22	0:44	1:06	8.7	43.0				X		
Gomphus vastus	6/4/2016	12:37	12:55	13:30	0:18	0:35	0:53	8.9	43.3				X		
Gomphus vastus	6/4/2016	11:02	11:16	12:05	0:14	0:49	1:03	10.0	45.3				X		
Gomphus vastus	6/4/2016	12:23	12:40	13:31	0:17	0:51	1:08	10.2	45.3					X	
Gomphus vastus	6/4/2016	12:10	12:23	13:10	0:13	0:47	1:00	10.3	45.3					X	
Gomphus vastus	6/4/2016	12:45	12:56	13:35	0:11	0:39	0:50	10.3	45.6					X	
Gomphus vastus	6/4/2016	11:34	11:58	12:23	0:24	0:25	0:49	13.1	49.9				X		
Gomphus vastus	6/4/2016	12:40	12:56	13:50	0:16	0:54	1:10	13.1	49.9				X		
Gomphus vastus	6/4/2016	11:31	11:51	12:26	0:20	0:35	0:55	5.7	30.5						
Gomphus vastus	6/4/2016	11:41	11:57	12:50	0:16	0:53	1:09	9.8	43.0				X		
Gomphus vastus	6/4/2016	12:28	12:45	13:19	0:17	0:34	0:51	10.8	47.2				X		
Gomphus vastus	6/7/2016	10:53	11:18	12:00	0:25	0:42	1:07	17.5	31.0			X			
Gomphus vastus	6/7/2016	10:41	11:05	11:59	0:24	0:54	1:18	9.7	30.0		X				
Gomphus vastus	6/7/2016	10:32	10:51	11:30	0:19	0:39	0:58	9.6	30.0			X			
Gomphus vastus	6/7/2016	11:08	11:31	11:45	0:23	0:14	0:37	12.2	28.0			X			
Gomphus vastus	6/7/2016	11:18	11:40	12:20	0:22	0:40	1:02	13.6	29.0			X			
Gomphus vastus	6/7/2016	11:10	11:32	12:02	0:22	0:30	0:52	11.5	29.0			X			
Gomphus vastus	6/7/2016	11:16	11:36	12:17	0:20	0:41	1:01	12.8	29.0			X			
Gomphus vastus	6/7/2016	11:28	11:43	12:19	0:15	0:36	0:51	10.5	27.0			X			

Gomphus vastus	6/7/2016	11:10	11:27	12:03	0:17	0:36	0:53	11.4	27.0			X			
Gomphus vastus	6/7/2016	11:10	11:31	12:12	0:21	0:41	1:02	11.7	27.0			X			
Gomphus vastus	6/7/2016	11:27	11:42	12:18	0:15	0:36	0:51	9.9	24.0			X			
Gomphus vastus	6/7/2016	11:47	12:00	12:43	0:13	0:43	0:56	13.1	22.0			X			
Gomphus vastus	6/7/2016	12:13	12:26	12:59	0:13	0:33	0:46	12.9	22.0			X			
Gomphus vastus	6/7/2016	10:42	11:03	11:47	0:21	0:44	1:05	13.2	18.5			X			
Gomphus vastus	6/7/2016	10:32	10:51	11:43	0:19	0:52	1:11	12.2	18.5			X			
Gomphus vastus	6/7/2016	10:30	10:51	11:30	0:21	0:39	1:00	10.2	18.5			X			
Gomphus vastus	6/7/2016	10:30	10:48	11:30	0:18	0:42	1:00	14.4	18.5			X			
Gomphus vastus	6/7/2016	12:18	12:30	13:15	0:12	0:45	0:57	14.4	18.5			X			
Gomphus vastus	6/7/2016	12:32	12:50	13:22	0:18	0:32	0:50	4.1	12.0			X			
Gomphus vastus	5/29/2015	11:42	12:12	12:58	0:30	0:46	1:16	5.1	1.0			X			
Libellulidae	7/2/2015	9:06	9:36	11:12	0:30	1:36	2:06	6.6	4.3				X		
Libellulidae	7/18/2015	12:58	13:28		0:30			8.2	30.8			X			Died
Libellulidae	5/30/2015	12:08	12:38	13:03	0:30	0:25	0:55	4.7	28.5			X			
Ophiogomphus rupinsulensis	7/2/2015	9:57	10:27	11:19	0:30	0:52	1:22	0.7	11.5	X					
Ophiogomphus rupinsulensis	5/30/2015	11:39	12:09	12:30	0:30	0:21	0:51	3.3	12.1			X			
Ophiogomphus rupinsulensis	5/30/2015	11:25	11:55	12:02	0:30	0:07	0:37	5.4	20.7	X					
Ophiogomphus rupinsulensis	5/30/2015	11:30	12:00	12:11	0:30	0:11	0:41	3.3	8.5	X					
Ophiogomphus rupinsulensis	5/30/2015	11:31	12:01	12:10	0:30	0:09	0:39	3.5	11.5	X					
Ophiogomphus rupinsulensis	5/30/2015	11:32	12:02	12:11	0:30	0:09	0:39	4.0	13.5	X					
Ophiogomphus rupinsulensis	5/30/2015	12:05	12:35	13:10	0:30	0:35	1:05	3.7	16.7				X		
Stylurus amnicola	6/20/2016	10:25	10:44	11:09	0:19	0:25	0:44	0.3	1.6	X					
Stylurus amnicola	6/20/2016	10:21	10:36	11:01	0:15	0:25	0:40	0.4	1.3	X					
Stylurus amnicola	6/27/2016	11:41	11:50	12:10	0:09	0:20	0:29	2.2	12.5	X					
Stylurus amnicola	6/27/2016	11:38	11:54	12:23	0:16	0:29	0:45	0.2	2.8	X					
Stylurus amnicola	7/2/2015	8:50	9:20	9:35	0:30	0:15	0:45	4.6	5.2			X			
Stylurus amnicola	7/7/2015	11:48	12:18	12:48	0:30	0:30	1:00	1.0	18.7	X					
Stylurus amnicola	7/9/2015	12:38	13:08	(17:03)	0:30	(3:55)	(4:25)	2.5	1.1		X				Outlier
Stylurus spiniceps	6/27/2016	10:20	10:31	11:06	0:11	0:35	0:46	3.4	14.8		X	X			
Stylurus spiniceps	6/27/2016	12:24	12:36	13:07	0:12	0:31	0:43	3.2	17.7	X					
Stylurus spiniceps	7/5/2016	17:11	17:20	17:46	0:09	0:26	0:35	5.4	26.9	X					
Stylurus spiniceps	7/5/2016	15:34	15:47	16:20	0:13	0:33	0:46	5.2	26.9	X					
Stylurus spiniceps	7/5/2016	16:34	16:45	17:22	0:11	0:37	0:48	5.6	27.6	X			X		
Stylurus spiniceps	7/5/2016	14:13	14:22	14:38	0:09	0:16	0:25	1.2	6.9	X					
Stylurus spiniceps	7/6/2016	12:57	13:07	13:26	0:10	0:19	0:29	0.1	0.0	X					
Stylurus spiniceps	7/6/2016	13:08	13:17	13:35	0:09	0:18	0:27	0.2	0.1	X					
Stylurus spiniceps	7/6/2016	14:57	15:07	15:29	0:10	0:22	0:32	0.2	1.0	X					
Stylurus spiniceps	7/6/2016	15:39	15:51	16:24	0:12	0:33	0:45	4.2	25.3				X		
Stylurus spiniceps	7/7/2016	9:31	9:41	10:08	0:10	0:27	0:37	0.2	3.3			X			
Stylurus spiniceps	7/7/2016	12:07	12:19	12:52	0:12	0:33	0:45	5.8	25.6		X				
Stylurus spiniceps	7/7/2016	12:38	12:48	13:14	0:10	0:26	0:36	0.0	0.0	X					
Stylurus spiniceps	7/7/2016	13:05	13:15	13:47	0:10	0:32	0:42	3.1	21.6	X	X				
Stylurus spiniceps	7/7/2016	10:49	11:00	11:27	0:11	0:27	0:38	0.2	1.0						
Stylurus spiniceps	7/7/2016	13:54	14:03	14:39	0:09	0:36	0:45	3.7	19.0			X			
Stylurus spiniceps	7/13/2016	9:39	9:46	10:05	0:07	0:19	0:26	2.2	6.2	X					
Stylurus spiniceps	7/13/2016	10:12	10:20	10:48	0:08	0:28	0:36	3.2	12.5	X			X		
Stylurus spiniceps	7/13/2016	10:18	10:26	10:42	0:08	0:16	0:24	2.5	13.8			X			
Stylurus spiniceps	7/13/2016	11:14	11:22	11:42	0:08	0:20	0:28	2.3	12.1		X		X		
Stylurus spiniceps	7/13/2016	11:55	12:02	12:25	0:07	0:23	0:30	3.3	10.8	X			X		
Stylurus spiniceps	7/9/2015	13:49	14:19	15:14	0:30	0:55	1:25	2.4	0.7		X				
Stylurus spiniceps	7/18/2015	15:25	15:55	16:34	0:30	0:39	1:09	4.6	21.7	X			X		
Stylurus spiniceps	7/18/2015	15:32	16:02	16:37	0:30	0:35	1:05	5.9	26.9	X					
Stylurus spiniceps	7/18/2015	15:37	16:07	16:44	0:30	0:37	1:07	5.3	25.3	X					

SHADING Start to Free time set to the maximum observed duration from the 2016 field season (30 minutes).

Relicensing Study 3.3.20

Ichthyoplankton Entrainment Assessment at the Northfield Mountain Project

2016 Study Report

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)

Prepared for:

FirstLight™ Power Resources

Prepared by:

Kleinschmidt GOMEZ AND SULLIVAN ENGINEERS

DECEMBER 2016

EXECUTIVE SUMMARY

FirstLight Hydro Generating Company (FirstLight) is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the Northfield Mountain and Turners Falls Projects using FERC's Integrated Licensing Process (ILP). The current licenses for the Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018. This report documents the results of Study No. 3.3.20 *Ichthyoplankton Entrainment Assessment at the Northfield Mountain Project* that was conducted during 2015 and 2016.

The February 21, 2014 FERC Study Plan Determination Letter (SPDL) did not require FirstLight to conduct ichthyoplankton sampling in the vicinity of the Northfield Mountain Project intake (tailrace) to quantitatively determine the level of entrainment of early lifestages of American Shad. On March 13, 2014, the United States Fish and Wildlife Service (USFWS) filed a notice of study dispute relating to this determination. On April 8, 2014, the Study Dispute Panel held a meeting at the Northfield Mountain Project Visitors Center to resolve the dispute. In the end, USFWS, FERC and FirstLight collaborated on a study plan to quantify entrainment of various lifestages of American Shad ichthyoplankton at the Northfield Mountain Project and the Study Dispute Panel was suspended without issuing a finding. FirstLight filed the study plan on October 16, 2014. FERC approved the plan in its study plan determination issued January 22, 2015.

In 2015, FirstLight conducted the ichthyoplankton entrainment study from May 28 to June 17 in accordance with the approved study plan. Over the course of the 2015 study, 23 entrainment samples and 12 validation samples were collected, processed and analyzed to estimate the number of American Shad eggs and larvae entrained at the Northfield Mountain Project. The shad ichthyoplankton densities in samples collected in entrainment and offshore at the Northfield Mountain Project were low, most likely because shad spawning did not occur in the proximity of the Northfield Mountain Project tailrace. When extrapolated to the volume of water pumped during the study period from May 28 to July 17, 2015 just over 3 million shad eggs and 500,000 shad larvae were estimated to have been entrained at the Northfield Mountain Project in 2015. Based on the entrainment estimates and published survival fractions (Crecco et al 1983), the number of equivalent juvenile and adults lost to entrainment at the Northfield Mountain Project in 2015 was estimated to have been 696 juvenile shad or 94 adult American shad.

Several stakeholders requested a second year of study and due to annual variability and the typical patchy distribution of ichthyoplankton and late start of the 2015 study, FirstLight performed a second year of study in 2016. Entrainment and offshore sampling was initiated on May 11, 2016 and continued at weekly intervals through July 29, 2016; 47 entrainment samples and 33 offshore (validation) samples were collected. Based on sample counts and the total volume of water pumped at Northfield Mountain Project during the 2016 study period, an estimated 9.5 million shad eggs and 5.4 million shad larvae were estimated to have been entrained the Northfield Mountain Project in 2016. Applying published survival fractions, the numbers of equivalent juvenile and adults lost to entrainment at the Northfield Mountain Project were estimated to be 2,093 juvenile shad or 578 adult American Shad. To put these numbers into perspective, the numbers of American Shad passed in 2016 at the Turners Falls Gatehouse fishway and the Vernon fishway were 54,069 and 35,807, respectively and the 2016 juvenile shad index of abundance was the highest ever recorded.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AELs	adult equivalent losses
C	Celsius
cfs	cubic feet per second
CI	confidence interval
CTDEEP	Connecticut Department of Energy and Environmental Protection
DO	dissolved oxygen
FERC	Federal Energy Regulatory Commission
FirstLight	FirstLight Hydro Generating Company
ft^2	square feet
ILP	Integrated Licensing Process
m^3	cubic meters
µS/cm	micro Siemens per centimeter
mg/L	milligrams per liter
mm	millimeter
msl	mean sea level
No.	number
Northfield Mountain Project	Northfield Mountain Pumped Storage Project
PAD	Pre-Application Document
PSP	Proposed Study Plan
QA/QC	Quality Assurance/Quality Control
RSP	Revised Study Plan
SD1	Scoping Document 1
SD2	Scoping Document 2
SPDL	Study Plan Determination Letter
TFI	Turners Falls Impoundment
TL	total length
Turners Falls Project	Turners Falls Hydroelectric Project
USFWS	United States Fish and Wildlife Service
VY	Vermont Yankee Nuclear Power Plant

1 INTRODUCTION

FirstLight Hydro Generating Company (FirstLight) is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the Northfield Mountain and Turners Falls Projects using the FERC's Integrated Licensing Process (ILP). The current licenses for Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018. This report documents the results of Study No. 3.3.20 *Ichthyoplankton Entrainment Assessment at the Northfield Mountain Project*.

As part of the ILP, FERC conducted a public scoping process during which various resource issues were identified. On October 31, 2012, FirstLight filed its Pre-Application Document (PAD) and Notice of Intent with the FERC. The PAD included FirstLight's preliminary list of proposed studies. On December 21, 2012, FERC issued Scoping Document 1 (SD1) and preliminarily identified resource issues and concerns. On January 30 and 31, 2013, FERC held scoping meetings for the two Projects. FERC issued Scoping Document 2 (SD2) on April 15, 2013.

FirstLight filed its Proposed Study Plan (PSP) on April 15, 2013 and, per the Commission regulations, held a PSP meeting at the Northfield Visitors Center on May 14, 2013. Thereafter, FirstLight held ten resource-specific study plan meetings to allow for more detailed discussions on each PSP and on studies not being proposed. On June 28, 2013, FirstLight filed with the Commission an Updated PSP to reflect further changes to the PSP based on comments received at the meetings. On or before July 15, 2013, stakeholders filed written comments on the Updated PSP. FirstLight filed a Revised Study Plan (RSP) on August 14, 2013 with FERC addressing stakeholder comments.

On August 27, 2013 Entergy Corp. announced that the Vermont Yankee Nuclear Power Plant (VY), located on the downstream end of the Vernon Impoundment on the Connecticut River and upstream of the two Projects, will be closing no later than December 29, 2014. With the closure of VY, certain environmental baseline conditions will change during the relicensing study period. On September 13, 2013, FERC issued its first Study Plan Determination Letter (SPDL) in which many of the studies were approved or approved with FERC modification. However, due to the impending closure of VY, FERC did not act on 19 proposed or requested studies pertaining to aquatic resources. The SPDL for these 19 studies was deferred until after FERC held a technical meeting with stakeholders on November 25, 2013 regarding any necessary adjustments to the proposed and requested study designs and/or schedules due to the impending VY closure. FERC issued its second SPDL on the remaining 19 studies on February 21, 2014, approving the RSP with certain modifications.

On March 13, 2014, the United States Fish and Wildlife Service (USFWS) filed a notice of study dispute relating to the FERC SPDL not to require FirstLight to conduct ichthyoplankton sampling in the vicinity of the Northfield Mountain Project intake (tailrace) to quantitatively determine the level of entrainment of early life stages of American Shad. Following USFWS letter, the following activities occurred relative to the study dispute:

- On March 26, 2014, a conference call was held with FirstLight, USFWS and FERC to discuss the notice of study dispute.
- On March 28, 2014, FirstLight filed with FERC information relative to Northfield Mountain Project Pumping.
- On March 31, 2014 FERC issued a Notice of Dispute Resolution Panel Meeting and Technical Conference.

- On April 1, 2014, a conference call was held with FirstLight, USFWS and FERC to further discuss the study dispute.
- On April 3, 2014, FirstLight filed with FERC two reports from the 1990s relevant to the Study Dispute Panel's consideration of the dispute.
- On April 7, 2014, FirstLight filed with FERC "Comments and Information of FirstLight Hydro Generating Company Regarding Notice of Study Dispute" relating to USFWS's exercise of Federal Power Act section 18 authority as it pertains to the study dispute.
- On April 8, 2014, the Study Dispute Panel held its meeting at the Northfield Mountain Project Visitors Center.
- On April 8, 2014, following the study dispute panel meeting, a meeting was held with FirstLight, USFWS and FERC to discuss the possibility of a mutually agreeable solution that would alleviate the need for a Director's determination on the study dispute.
- On April 14, 2014, FirstLight filed with FERC drawings and photographs of the Northfield Mountain Project relevant to study methodology discussed by FirstLight, USFWS, and FERC.
- On April 15, 2014, FirstLight filed with FERC Dye testing information conducted at the Northfield Mountain Project.
- On April 22, 2014, a conference call was held with FirstLight, USFWS and FERC to further discuss a mutually agreeable study plan.
- On May 1, 2014, the USFWS filed a Response to the FirstLight's April 7, 2014 filing.
- On May 2, 2014, the USFWS filed with FERC a conceptual framework for assessing ichthyoplankton entrainment at the Northfield Mountain Project. In addition, in a separate May 2, 2014 letter to FERC, USFWS stated that if FERC accepts the proposed study plan framework and requires FirstLight to conduct the study, USFWS will consider the dispute resolved.
- On May 2, 2014, FirstLight filed with FERC a letter supporting USFWS's proposed study.
- On May 2, 2014, FERC suspended the Dispute Resolution Panel.

In the end, USFWS, FERC and FirstLight collaborated on the study plan to quantify entrainment of various life stages of American Shad ichthyoplankton (eggs, yolk-sac and post yolk-sac larvae) at the Northfield Mountain Project. FirstLight submitted the study plan on October 16, 2014, and FERC approved the plan with modifications in its January 22, 2015 study plan determination. Specifically, FERC modified the study plan by recommending that FirstLight (1) include river discharge in its analyses of ichthyoplankton density and entrainment rates; and (2) examine the relationship between entrainment and intake water volume.

1.1 Study Goals and Objectives

In 2015, FirstLight conducted the ichthyoplankton entrainment study from May 28 to June 17. The report describing the 2015 study results was filed with FERC on March 1, 2016. On April 25, 2016 FirstLight had a conference call with NMFS, USFWS, FERC and MADFW to discuss the 2015 ichthyoplankton study. A number of stakeholders requested a second year of study. Due to starting the study late in 2015 coupled with annual variability and the typical patchy distribution of ichthyoplankton, FirstLight performed a second year of study in 2016, which is reported herein. As identified in the Study Plan, the purpose of this study is to quantify entrainment of American Shad ichthyoplankton at the Northfield Mountain Project. The objectives of this study are to:

- 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;
- Compare entrainment rates with one through four units pumping; and
- Determine the temporal distribution of entrainment within the prevailing pumping period.

In their comments on the 2015 report, several stakeholders requested that FirstLight calculate ichthyoplankton entrainment based on pumping operation during the shad ichthyoplankton period under FirstLight's proposal to expand the Upper Reservoir's operating range. The modeling for this scenario is in development, and FirstLight will include the results of the ichthyoplankton entrainment projection based on this scenario in a future filing with FERC.

2 STUDY SITE

The Northfield Mountain Project consists of: a) an upper reservoir and dam/dikes; b) an intake in the upper reservoir; c) pressure shaft; d) an underground powerhouse; and e) a tailrace/intake in the lower reservoir. The Turners Falls Impoundment (TFI) (Connecticut River) serves as a lower reservoir. During generation, water flows from the upper reservoir via the intake channel, through the pressure shaft to the powerhouse and then the tailrace tunnel delivers the water back to the TFI. Key features are described further below.

Turners Falls Impoundment

The TFI, formed by the Turners Falls Dam, extends upstream approximately 20 miles to the base of Vernon Dam in Vernon, VT. To provide storage capacity for the Northfield Mountain Project, the Turners Falls Impoundment elevation may vary, per the FERC license, from a minimum elevation of 176.0 feet msl to a maximum elevation of 185.0 feet msl; this constitutes a 9 foot fluctuation as measured at the Turners Falls Dam. The impoundment has a surface area of approximately 2,110 acres and a gross storage volume of approximately 21,500 acre-feet at elevation 185.0 feet msl (as measured at Turners Falls Dam).

Northfield Mountain Intake/Tailrace Tunnel

During pumping operation, water is pumped from the TFI through a tailrace tunnel to the powerhouse cavern and then through the pressure shaft to the upper reservoir. A floating boom is provided across the intake channel to provide a barrier to large debris and boaters. The trapezoidal trashrack opening has the following dimensions: top width: 99’-6”, bottom width: 74’4”, depth: 48’-0”, resulting in a gross area opening of 4,400 ft2. The bar thickness is 0.75 inches, with a clear-spacing of 6 inches. The intake structure includes a transition from the trapezoidal shape into a horseshoe shaped tunnel. There are four draft tubes connected by a manifold to a common tailrace tunnel. The tailrace tunnel is concrete lined, horseshoe shaped and 5,136 feet long, with a maximum width of 33 feet and a height of 31 feet.

Powerhouse

The underground powerhouse is 328 feet long and 70 feet wide. The floor of the spherical valve gallery is at elevation 56 feet mean sea level (msl) and the roof is at 190 feet msl. It contains four reversible pump/turbines operating at gross heads ranging from 753 to 824.5 feet. The electrical capacities of the units during the study period were as follows: Unit 1: 267.9 MW, Unit 2: 291.7 MW, Unit 3: 291.7 MW and Unit 4: 291.7 MW, for a total station nameplate capacity of 1,143 MW. When operating in a pumping mode, the approximate hydraulic capacity is 15,200 cfs (3,800 cfs/pump). Alternatively, when operating in a generation mode, the approximate hydraulic capacity is 20,000 cfs (5,000 cfs/turbine).

Pressure Shaft

During pumping, water from the powerhouse enters the pressure conduit system which consists of four steel-lined penstocks (340 feet long, diameter increased from 9.5 to 14 feet). These penstocks come together into two 22 foot diameter conduits and then into concrete-lined manifold. An inclined concrete-lined pressure shaft 31 feet diameter, 853 feet long, inclined 50º from the horizontal) connects the manifold to a 200 foot long concrete lined transition section and then to the upper reservoir intake portal. From here, water enters the upper reservoir.

3 METHODS

Ichthyoplankton monitoring at the Northfield Mountain Project consisted of both entrainment and river sampling to determine the number of American Shad larvae and eggs that are withdrawn from the Connecticut River and pumped to the upper reservoir. In 2016, entrainment and river sampling during pumping operations were initiated on May 11 (calendar week 20 of 2016) and generally continued at weekly intervals through July 29 (calendar week 31 of 2016). During the first year of study (2015), operations at the Northfield Mountain Project were intentionally manipulated such that sample collection occurred during 1, 2, 3, and 4-pump operations. For the 2016 study, no attempt was made to schedule sampling during specific pumping scenarios.

3.1 Entrainment Sampling

Similar to 2015, entrainment sampling to collect American Shad eggs and larvae in 2016 was accomplished by tapping off existing piping for Unit 2 in the Northfield Mountain powerhouse that supplies water from the Connecticut River to the upper reservoir. The water diverted at the tap represented the raw water pumped through the system. PVC and rubber piping, a digital flow meter, a 1,000-liter plastic tank, and a 0.333 mm mesh plankton net were utilized to construct the sampling system (Figure 3.1-1). In 2016, the goal was to filter approximately 50 cubic meters (m^3) of intake water per sample to assess the temporal trends in entrainment during the approximately 6-hour pumping period each night. Intake water was diverted to the entrainment sampler at a rate of approximately 3-3.5 gallons per second, which allowed for each sample to be collected in about one hour. Entrainment sample collection was initiated at least ½-hour after the pumping cycle began to allow for the water to be well-mixed. As such, 3 to 5 replicates (50 m^3 each) were collected each sampling night.

Intake water from Unit 2 was diverted through a four-inch diameter flexible hose to a 1,000-liter entrainment sampling tank. An inline Signet® digital flow meter was mounted in the hose to record the volume of water sampled. The hose discharge was directed into a conical 0.333 mm mesh plankton net suspended in a 1,000-liter plastic tank. The plastic tank was designed with an overflow system. Once sufficient volume was obtained, the net was removed from the sampling tank and its contents rinsed into the cod-end collection jar with fresh water. The sample jar was then removed from the plankton net and the contents preserved with a 10% formalin solution for subsequent sorting in the laboratory.

3.2 Sample Validation

To validate that ichthyoplankton collection densities were representative of densities in the intake tunnel, paired samples from inside of the powerhouse (entrainment) and from the intake/tailrace channel (offshore) were generally collected each week. No offshore samples were collected during the week beginning May 22, 2016 as the bongo nets could not be retrieved following deployment on the night of May 24, 2016 (or early morning May 25).

Ichthyoplankton samples were collected near the entrance to the intake/tailrace channel with weighted 60-cm diameter paired bongo nets with 0.333 mm mesh deployed from a boat. The general location of the tows is shown in Figure 3.2-1. The bongo nets were generally towed obliquely[1] in a straight line from downstream to upstream for approximately six minutes or until at least 100 cubic meters of river water was sampled. General Oceanics flowmeters were suspended in the center of each net to measure the volume of river water filtered during each tow. Once the target volume was obtained based on time towed, the nets were hauled onto the boat and the contents from the net with the highest volume were rinsed down with water into the cod-end collection jars; the contents of the other net were discarded. Three replicate tows

[1] The 2015 report submitted to FERC in February 2016 incorrectly stated that the bongo system was towed at mid-depth. The net was towed in an oblique pattern during both years of study, such that the bongos were first deployed to sample near-bottom and gradually raised towards the surface to allow for the entire water column to be sampled.

were performed on each sampling night. The samples were preserved with a 10% formalin solution in appropriately labeled jars and transported back to the sorting room for analysis.

3.3 Sample Processing

Samples were sorted with the aid of a dissecting microscope by biologists trained in ichthyoplankton identification. American Shad larvae and eggs were removed from the samples, identified, and enumerated. Larvae and eggs of Blueback Herring and American Shad in the Connecticut River are not easily distinguishable. However, Blueback Herring numbers are very low; therefore, any alosine eggs and larvae were assumed to be American Shad.

A quality control (QC) program designed to ensure that the Average Outgoing Quality Limit for sorting and identification is greater than 90% was followed. To accomplish this, one sample from each series of ten samples processed by a single individual was randomly selected to be re-sorted. No one was allowed to perform a quality assurance/quality control (QA/QC) on his or her own samples. The person checking the sample (the QA/QC-er) re-processed the sample to determine what percentage of both larvae and eggs was missed, if any. If the percentage missed in either category was equal to or greater than 10%, the following QA/QC procedure was followed until a "passing" QA/QC was obtained: Starting with samples sorted prior to the failed QA/QC, samples were re-sorted in sequential order, working back, until a 'passing' QA/QC was obtained (i.e., Number found by QA/QC individual was less than 10% of total eggs or larvae in the sample). The process was repeated with subsequently sorted samples, sequentially until a passing QA/QC was obtained. Any larvae or egg found during the QA/QC process was added to the totals on the corresponding data sheet and included in the entrainment estimates.

All sorting data, as well as field data, were entered into a Microsoft Access database developed specifically for this study. All data entered were verified for accuracy against the original data sheets prior to commencement of analyses, which are described below.

3.4 Entrainment Data Analysis Methods

Sample Densities

The densities of shad eggs and larvae in each of the entrainment and offshore samples were calculated by dividing the sample count by sample volume to express organism density in count per cubic meter (1).

$$\rho_{si} = \frac{x_{si}}{v_s} \qquad (1)$$

Where ρ_{si} is the density of lifestage i (eggs or larvae) in sample s (org/m^3); x_{si} is the count of organisms of lifestage i in sample s (org); and v_s is the volume of sample s (m^3). There is no uncertainty associated with an individual sample density as there is a single count and single volume that are considered for the density calculation.

Weekly Sample Densities

Equation (2) calculates a weekly mean entrainment density and the uncertainty is accounted for with Equation (3). The mean counts with 95% confidence intervals (CI) were calculated assuming a Poisson distribution using a generalized linear model with count as the dependent variable and week as a factor. The Poisson distribution assumes that the count variance equals the mean. If this assumption failed, the mean counts and 95% CI were estimated with a generalized linear model assuming a Negative Binomial distribution.

$$\rho_{wi} = \frac{e^{\bar{x}_{wi}}}{\bar{v}_w} \qquad (2)$$

Where $\rho_{wi}$is the density of lifestage i in week w and is expressed in units of x/m^3; $\bar{x}_{wi}$ is the mean count of lifestage i in week w (x); and $\bar{v}_w$ is the mean sample volume (m^3) in week w. Equation (3) estimates the uncertainty in ρ_{wi} and assumes that the errors associated with count $\bar{x}_{wi}$ and sample volume $\bar{v}_w$ are uncorrelated and random.

$$\delta\rho_{wi} = \sqrt{\left(\frac{\delta\bar{x}_{wi}}{\bar{x}_{wi}}\right)^2 + \left(\frac{\delta\bar{v}_w}{\bar{v}_w}\right)^2} * |\rho_{wi}| \quad (3)$$

Where $\delta\rho_{wi}$ is the 95% CI of the mean density of lifestage i in week w; $\delta\bar{x}_{wi}$ is the 95% CI of the mean count of lifestage i in week w (Equation (4)); and $\delta\bar{v}_w$ is the 95% CI of volume in week w (Equation (5)).

$$\delta\bar{x}_{wi} = Z_{a/2} * \frac{\sigma_{x_{wi}}}{\sqrt{n}} \quad (4)$$

$$\delta\bar{v}_w = Z_{a/2} * \frac{\sigma_{v_w}}{\sqrt{n}} \quad (5)$$

Where $\sigma_{x_{wi}}$ and σ_{v_w} are the standard deviation of weekly counts (x) and volume (v), respectively, and $Z_{a/2}$ is the Z-score for the 95% confidence level (α). If the precision of the weekly sample densities cannot be estimated, a more traditional extrapolation method is warranted. First, weekly sample densities given with Equation 6 are calculated.

$$\bar{\rho}_{wi} = \frac{\sum x_{si}}{\sum v_s} \quad (6)$$

Where $\bar{\rho}_{wi}$ is the weekly density of the i^{th} species and lifestage, x_{si} is the count of the i^{th} species and lifestage in sample s and v_s is the volume of water pumped in sample s. Following the calculation of each weekly density, a linear spline interpolated daily organism densities (org/m^3) between weekly observations. The spline method interpolates a linear function between observations and assumes that observations taken closer together are more similar than those taken further apart. Following the calculation of daily densities, the estimate was extrapolated by multiplying the daily density by the daily summed pumping flow.

Comparison of Offshore and Entrainment Samples

Following the calculation of weekly entrainment and offshore densities by lifestage, the sample type (entrainment or offshore) with the maximum density estimate served as the weekly extrapolation density. Based on the number of samples, direct comparisons were made with an aggregate query in Microsoft Access that determined the maximum weekly lifestage density. Following this comparison, operations data were manipulated as described below for the weekly extrapolation.

Calculation of Flow

Northfield Mountain operations data for the duration of the entrainment sampling program were provided by FirstLight as hourly flow rates (cfs). As the entrainment extrapolation requires the total amount of water pumped during a given calendar week, the flow rate was transformed to a volume of water pumped (Equation (7)).

$$Q_i' = Q_i * 0.0283168 * s_i \quad (7)$$

Where Q_i' is the volume of water pumped (m^3) per Northfield Mountain Project time interval i; Q_i is the Northfield Mountain Project reported flow rate in ft^3/s; s_i is the duration of the i^{th} Northfield Mountain Project time interval in seconds; and the conversion factor is expressed in units of cubic meter per second per cubic foot per second ($^{m^3/s}/_{ft^3/s}$). A Microsoft Access aggregate query summed the weekly volume of water pumped that was used to extrapolate weekly entrainment estimates.

Weekly Extrapolation of Entrainment Estimates

Entrainment estimates for American Shad eggs and larvae were derived based on the extrapolation of raw counts using a volumetric ratio and summing of weekly estimates derived from samples. The weekly entrainment estimate was calculated by multiplying the organism density ρ_{wi} (org/m^3) by the volume of water pumped in a given week (m^3) (Equation (8)).

$$x'_{wi} = \rho_{wi} Q'_w \tag{8}$$

Where x'_{wi} is the weekly estimate of organisms entrained during pumping operations; ρ_{wi} is the weekly entrainment density expressed in $\ln(x_{wi})\ /m^3$; and Q'_w is the sum of water pumped during week w. While there is no error associated with Q'_w, the error associated with each weekly estimate ρ_{wi} was calculated. Equation (9) calculates the error associated with each weekly estimate x'_{wi}.

$$\delta x'_{wi} = |Q'_w| * \delta \rho_{wi} \tag{9}$$

Where $\delta x'_{wi}$ is the uncertainty of the weekly extrapolation, and the weekly volume Q'_w and density uncertainty $\delta \rho_{wi}$ were derived with Equations (7) and (3), respectively. The weekly extrapolation estimates the number of individuals of lifestage i entrained due to pumping operations at the Northfield Mountain Project while the Adult Equivalent Model estimates the number of equivalent adults that are lost to recruitment.

Equivalent Adult Estimates

The numbers of entrained American Shad larvae and eggs during sampling at Northfield Mountain were converted into adult equivalents. Adult equivalent losses (AELs) are estimates of the number of entrained organisms removed from the population that otherwise would have survived to some future age, or age of equivalence. To estimate AELs for Northfield Mountain, the weekly estimates of entrained larvae and eggs (x'_{wi}) were multiplied by the survival fraction at the age of equivalence i and the proportion p of returning adults that belong to lifestage i (Equation (10)):

$$AEL_j = \sum_{j=1}^{n} S_{ij} x'_{wi} p_j \tag{10}$$

Where AEL_j is the expected number of adult equivalents of lifestage j lost due to pumping operations; S_{ij} is the survival fraction of organisms of starting lifestage i surviving to lifestage j; x'_{wi} is the extrapolated number of organisms of lifestage i during week w; and p_j is the expected proportion of returning equivalent adults of lifestage j.

Survival rates of early lifestages are often expressed on a lifestage-specific basis so that the fraction surviving from any particular lifestage i to adulthood or age of equivalence j is expressed as the product of survival fractions for all lifestages (k) through which a fish must pass before reaching age of equivalence j (Equation (11)).

$$S_{ij} = \prod_{i=1}^{j} S_k \quad (11)$$

Where S_{ij} where is the survival fraction from the starting age i to the age of equivalence j and S_k is the survival rate at age k. Lifestage-specific survival rates were compiled from (EPA 2004) and Crecco et al. 1983 (Table 3.4.1). Both sources reported mortality rather than survival. Mortality was converted to survival with Equation 12 (Haddon, 2011):

$$S_k = \frac{N_k}{N_i} = e^{-(M_k + F_k)} \quad (12)$$

Where M_k is the natural mortality rate at lifestage k; F_k is the fishing mortality at lifestage k; and N_k is the number expected to survive to lifestage k assuming N_i is the number of fish alive at lifestage i.

The Connecticut Department of Energy and Environmental Protection (CT DEEP) collects life history parameters from adult American Shad as they pass through the Holyoke lift and uses scales to estimate the age of the fish. The ages of equivalence are based on the list of ages identified by the CT DEEP over a 5-year period from 2010 – 2014 (J. Benway, CT DEEP, personal communication, 12/2015). The yearly counts by age introduce uncertainty into the proportion of returning adults p belonging to the age of equivalence$j$. The 95% CI for the proportion of each age class was calculated assuming a multinomial distribution. The uncertainty associated with x'_{wi} and p_j was accounted for with Equation (13).

$$\delta AEL_{wj} = \sqrt{\left(\frac{\delta x'_{wi}}{x'_{wi}}\right)^2 + \left(\frac{\delta p_j}{p_j}\right)^2} * \left|AEL_{wj}\right| \quad (13)$$

Where δAEL_{wj} is the uncertainty in the estimated AEL_j ; $\delta x'_{wi}$ is the 95% CI of the weekly (w) extrapolation of lifestage i; x'_{wi} is the weekly w extrapolation of lifestage i ; δp_j is the 95% CI for the proportion of the j^{th} age of equivalence; and p_j is the proportion of the j^{th} lifestage that are expected to return to the Holyoke lift. The AEL model was implemented to take advantage of its inherent looping and hash table indexing capabilities. Following computation, results were imported into the Microsoft Access project database. An aggregate query then summed the number of equivalent adults over each week to obtain the number of equivalent adults for each recruitment age lost to entrainment in 2016.

Table 3.4-1. Lifestage Specific Mortality Rates with Converted Survival Fractions

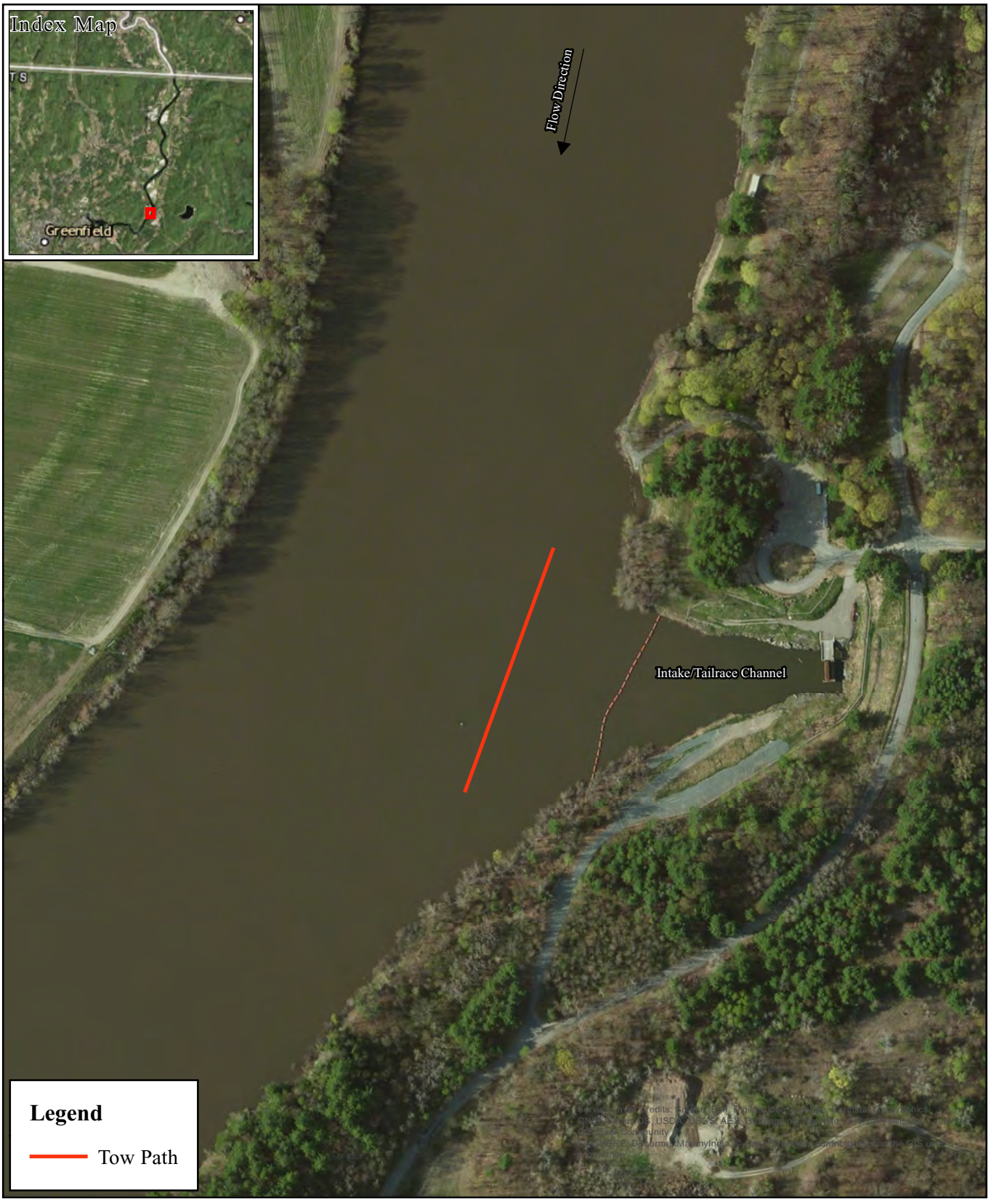
Lifestage (k)	M_k	F_k	S_k	Source
Egg	0.496	0	0.609	EPA 2004
Larvae 1 (L1)	0.273	0	0.760	Crecco *et.al.,* 1983
Larvae 2 (L2)	0.15	0	0.861	Crecco *et. al.,* 1983
Larvae 3 (L3)	0.096	0	0.901	Crecco *et. al.,* 1983
Larvae 4 (L4)	0.060	0	0.942	Crecco *et. al.,* 1983
Juvenile	7.4	0	6.113×10^{-4}	EPA 2004
Age 1	0.3	0	0.741	EPA 2004
Age 2	0.3	0	0.741	EPA 2004
Age 3	0.3	0	0.741	EPA 2004
Age 4	0.54	0.21	0.472	EPA 2004
Age 5	1.02	0.21	0.292	EPA 2004
Age 6	1.5	0.21	0.181	EPA 2004

Note: from Crecco et. al., 1983, the lifestages specific mortality rates were averaged across 1979 – 1982.

Note: L1 larvae correspond to fish between 10.0 and 13.0 mm, L2 fish between 13.0 and 18.0 mm, L3 fish between 18.0 and 21.0 mm and L4 fish are between 21.0 and 23.0 mm.

Note: M_k is the instantaneous rate of natural mortality at lifestage k; F_k is the instantaneous rate of fishing mortality at lifestage k; and S_k is the lifestage specific survival fraction.

Figure 3.1-1: Ichthyoplankton Entrainment Sampling System for Collection of American Shad Eggs and Larvae at the Northfield Mountain Project.



FirstLight Power Resources

Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)

Ichthyoplankton Entrainment Assessment at the NorthfieldMountain Project Relicensing Study 3.3.20

N

0 0.025 0.05 0.1 Miles

Figure 3.2-1: General Location of Ichthyoplankton Entrainment Verification Samples

Path: W:\gis\studies\3_3_20\Maps\Figure 3_2_1.mxd

4 RESULTS

Over the course of the study, 47 entrainment samples and 33 validation (offshore) samples were collected between May 11 (calendar week 20 of 2016) and July 29, 2016 (calendar week 31 of 2016). Water quality information, including water temperature, dissolved oxygen (DO), pH and conductivity, collected on each date of sampling, as well as operational status of the Northfield Mountain Project, is presented in Table 4.0-1 for entrainment and Table 4.0.2 for validation samples. During sampling, the water temperature ranged from 11.7°C to 26.8°C, DO ranged from 6.5 to 11.7 mg/L, pH ranged from 7.1 to 8.4 and conductivity 63 to 157 µS/cm for entrainment and validation samples combined. Figure 4.0-1 shows the Connecticut River flow as measured at the United States Geological Survey gage in Montague City, MA (Gage No. 01170500) during the sampling period.

4.1 Entrainment Densities

Weekly densities, based on the total number of organisms collected and total volume of water sampled each week of entrained shad eggs and larvae are presented in Table 4.1-1. Eggs were first observed in entrainment samples collected on June 2 (Week 23) and remained present in samples collected through July 8, 2016 (Week 28). Egg density peaked during Week 24 (June 8), when a maximum density of 15.3 eggs per 100 m3 was observed.

Larval observations appeared somewhat more sporadic as larvae were absent from 50% of the samples collected. Shad larvae were first observed in entrainment samples collected on May 25 and peak density occurred on June 8, 2016 (Week 24). Shad larvae were not observed in any samples collected after July 8, 2016 (Week 28). Weekly larval densities ranged from 0 to 11.5 shad larvae per 100 m^3.

The temporal distribution of shad egg and larval entrainment was assessed by summing hourly (based on start hour) densities for each lifestage (eggs and larvae) across weeks (Table 4.1-2). There was no temporal distribution throughout the sampling period.

There does not appear to be a trend with river flow and entrainment density. The daily non-zero organism densities (org/m^3) were matched with the daily average flow at the Montague USGS gage and graphed (Figure 4.1-1). There does not appear to be a trend with river flow and entrainment at Northfield as the Pearson correlation coefficient was low for eggs (r = 0.49) and larvae (r = -0.35).

4.2 Verification (Offshore) Densities

Verification (offshore) sampling was conducted adjacent to Northfield Mountain intake/tailrace channel each evening that entrainment samples were collected. No verification samples were collected during Week 22 as one of the nets was torn during the first tow and could not be replaced until the following week. Weekly densities of shad eggs and larvae in verification samples are presented in Table 4.2-1. Throughout the 2016 study period, only one shad egg was observed in the verification samples, which was collected on May 18 (Week 21).

Larval observations were also scarce, with larvae only observed in samples collected during Weeks 24 (June 8) and 25 (June 17). The density of shad larvae in the verification samples collected during Week 24 was 0.311 larvae per 100 m^3 and for Week 25 was nearly 11 larvae per 100 m^3. No larvae were collected after June 17, 2016 (Week 25).

4.3 Entrainment Estimate

Both the entrainment and offshore densities were used to calculate weekly entrainment estimates. With multiple samples collected per night and week, uncertainty in organism density was taken into account. It is assumed that organism density within the river is variable in space and time. The entrainment density should reflect that natural variability. Therefore, the weekly mean count and 95% CI were modeled with a generalized linear model. Count data are traditionally modeled assuming a Poisson distribution; however, sample counts at the Northfield Mountain Project violated the assumption of the variance equaling the mean (Table 4.3-1). As in 2015 a generalized linear model assuming a negative binomial distribution was used to model the mean count and CI, with week as a factor.

To describe the mean weekly entrainment rate, we applied a negative binomial regression to the larval entrainment data. The test, which was analogous to a traditional analysis of variance, looked for significant difference in mean count over each week. However, neither the intercept (Table 4.3-2) nor any week of the larval entrainment data were significant. Therefore, a negative binomial distribution was fit to the entire entrainment dataset (Figure 4.3-1). While excellent fit was achieved (note very high agreement between empirical and theoretical distributions), the overabundance of samples with 0 counts meant the distribution was not informative for extrapolation purposes. Both the median and lower 95% confidence interval were zero, meaning our estimate would be zero. This result prompted the use of a more traditional entrainment estimate.

With this information in mind, we developed an extrapolation that mirrors a more traditional method that simply multiplies the daily sample density by the total volume of water pumped. This method cannot give us an estimate of precision. We interpolated organism densities (org/m^3) between observations with a linear spline for 2016 (Figure 4.3-2). Note the spline method interpolates a linear function between observations. This method assumes that observations taken closer together are more similar than those taken further apart. The 2016 entrainment estimate was 9,540,864 eggs and 5,385,760 L4 larvae (Table 4.3-2).

4.4 Equivalent Adult Estimates

Similar to 2015, the estimate of equivalent adults by lifestage incorporated the proportion of 3, 4, 5, and 6-year-old adults returning to Holyoke between 2010 and 2014 (J. Benway CT DEEP pers. comm. 12/2015). The age with the highest proportion of returning adults was five (5) with just over 40% (Table 4.4-1). Results of the equivalent juvenile and adult determinations for American Shad observed in the 2016 entrainment samples are provided in Table 4.4-2. To be conservative, it was assumed that all larvae entrained at Northfield Mountain during 2016 were of lifestage L4 as this class exhibits the highest lifestage-specific survival amongst the various stages of shad larvae. The total number of equivalent juvenile and adult American Shad lost due to entrainment of eggs and larvae at the Northfield Mountain Project in 2016 was estimated to be 2,093 juveniles or 578 adult American Shad.

4.5 Shad Spawning in TFI

A companion American Shad spawning study was conducted in the TFI during 2015 (Study No. 3.3.6 *Impact of Project Operations on Shad Spawning, Spawning Habitat and Egg Deposition in the Area of the Northfield Mountain and Turners Falls Projects*). The only area where shad were detected spawning in the TFI was just below the Vernon Dam at the downstream end of Stebbins Island (Figure 4.5-1). Spawning was observed over an approximately 39-acre area at this location. As part of Study No. 3.3.6, American Shad eggs and larvae were collected at the Stebbins Island spawning site and the densities from May 19 to June 18, 2015 ranged from 7 to 101 per 100 m^3 (*see* Study Report No. 3.3.6).

Table 4.0-1. Northfield Mountain Project Entrainment Sample Collection Information

Week No.	Sample Date	Sample No.	Start Time	Duration (hr:min)	No. of Pumps	Water Temp. (ºC)	DO (mg/L)	pH	Conductivity (µS/cm)
20	5/11/2016	1	0:31	1:11	2	11.69	11.4	7.95	98
		2	2:14	1:07	2	11.86	11.65	7.99	99
		3	3:28	1:08	1	11.86	11.51	7.79	99
21	5/18/2016	4	0:45	1:07	2	13.25	10.93	7.77	102
		5	1:53	1:07	3	12.99	10.73	7.81	102
		6	3:05	1:13	3	12.85	10.76	7.81	101
		7	4:20	1:20	1	12.70	10.77	7.8	101
22	5/25/2016	8	0:40	0:59	4	15.08	10.12	7.83	97
		9	1:40	1:01	4	*	*	*	*
		10	2:42	1:01	4	*	*	*	*
		11	3:44	0:57	3	*	*	*	*
		12	4:42	1:03	2	*	*	*	*
23	6/2/2016	13	2:45	1:10	2	21.78	8.28	7.57	122
		14	4:00	1:08	3	21.67	9.26	7.48	122
		15	5:10	1:07	1	21.57	8.11	7.48	121
24	6/8/2016	16	1:30	1:10	1	22.04	8.05	7.44	124
		17	2:43	1:05	2	21.99	8.04	7.48	124
		18	3:50	1:10	3	21.91	8.01	7.49	124
		19	5:03	1:10	3	21.86	8.05	7.49	124
25	6/17/2016	20	0:50	1:08	3	21.66	9.17	7.31	124
		21	3:19	1:06	4	20.73	9.29	7.74	123
		22	4:28	1:07	2	20.64	9.25	7.71	123
26	6/23/2016	23	1:28	1:05	2	22.18	8.64	7.51	137
		24	2:35	1:05	3	22.37	9.11	7.73	143
		25	3:42	1:08	2	22.23	9.14	7.78	144
		26	4:50	1:08	1	22.14	9.07	7.77	144
27	6/29/2016	27	0:40	1:08	1	23.99	7.92	7.63	147
		28	1:50	1:06	2	24.11	8.04	7.63	146
		29	2:58	1:08	3	24.19	8.11	7.65	146
		30	4:08	1:10	1	24.05	8.00	7.64	146
28	7/8/2016	31	0:55	1:01	2	25.90	8.75	7.95	141
		32	1:57	1:07	3	25.88	8.71	8.16	140
		33	3:05	1:10	4	25.79	8.7	8.12	140
		34	4:16	1:09	3	25.68	8.69	8.11	138
29	7/15/2016	35	23:45**	1:10	1	24.55	8.39	7.95	140
		36	0:55	1:09	2	24.82	9.04	8.13	142
		37	2:05	1:04	3	24.82	8.85	8.13	143

Week No.	Sample Date	Sample No.	Start Time	Duration (hr:min)	No. of Pumps	Water Temp. (ºC)	DO (mg/L)	pH	Conductivity (µS/cm)
		38	3:10	1:02	4	24.72	8.94	8.13	142
		39	4:12	1:05	2	24.72	8.80	8.13	141
30	7/20/2016	40	0:27	1:15	1	25.36	8.81	8.20	157
		41	1:42	1:14	2	25.16	8.80	8.20	157
		42	2:56	1:14	2	25.02	8.65	8.18	155
		43	4:10	1:15	2	24.91	8.70	8.20	154
31	7/29/2016	44	0:40	1:04	2	26.25	8.35	8.40	146
		45	1:45	1:07	3	26.22	8.22	8.11	145
		46	2:55	1:09	3	26.33	8.32	8.14	144
		47	4:05	1:07	2	26.37	8.28	8.13	143

** No measurements recorded; water quality meter malfunctioned.*

*** Sample initiated on night of 7/14, but completed on 7/15/2016.*

Table 4.0-2. Northfield Mountain Project Validation (Offshore) Sample Collection Information

Week No.	Sample Date	Water Temp. (°C)	DO (mg/L)	pH	Conductivity (µS/cm)	Sample No.	Start Time	Duration (minutes)	Depth (ft)	Sample Volume (m^3)	No. of Pumps
20	5/11/2016	12.3	10.3	7.05	63	1	2:35	7	35	105	2
						2	3:15	7	35	116	2
						3	3:46	7	35	117	2
21	5/18/2016	13.5	9.62	7.26	77	4	1:18	6	20	198	2
						5	1:44	6	18	164	2
						6	2:03	6	20	106	2
22	6/2/2016	21.9	7.75	7.38	100	7	2:21	6	20	100	2
						8	2:57	6	19.2	101	2
						9	3:12	6	20	105	2
23	6/10/2016	20.3	7.65	7.55	112	10	3:03	5	-	111	2
						11	3:19	6	-	105	2
						12	3:36	6	-	106	1
24	6/17/2016	20.8	7.89	7.47	117	13	0:59	6	22.4	137	3
						14	1:14	6	23.7	116	3
						15	1:31	6	24	112	3
25	6/23/2016	22.3	7.61	7.47	102	16	2:05	6	25	157	2
						17	2:20	6	23.2	148	2
						18	2:33	6	25	140	2
26	6/29/2016	24	7.18	7.57	118	19	3:55	6	-	142	4
						20	4:16	6	-	213	3
						21	-	6	-	130	3
27	7/8/2016	26.5	7.36	7.62	131	22	1:15	6	20	118	2
						23	1:35	6	20	106	2
						24	2:03	6	20	120	3
28	7/15/2016	25.4	6.92	7.7	132	25	0:00	6	17	150	1
						26	0:19	6	20	104	1

Week No.	Sample Date	Water Temp. (°C)	DO (mg/L)	pH	Conductivity (µS/cm)	Sample No.	Start Time	Duration (minutes)	Depth (ft)	Sample Volume (m^3)	No. of Pumps
						27	0:34	6	23	127	2
29	7/20/2016	25.7	7.18	7.5	140	28	0:45	6	20	117	1
						29	1:01	6	20	122	1
						30	1:15	6	20	114	1
30	7/29/2016	26.8	6.51	7.49	129	31	0:56	6	20	115	1
						32	1:11	6	20	111	1
						33	1:24	6	20	100	1

"-" no data recorded

Table 4.1-1. 2016 Weekly Densities of American Shad Ichthyoplankton Observed in Entrainment Samples

Week No.	Lifestage	Count	Sample Volume (m^3)	Density (No./100 m^3)
20	E	0	150	0.000
	L	0		0.000
21	E	0	201	0.000
	L	0		0.000
22	E	0	250	0.000
	L	2		0.800
23	E	20	148	13.514
	L	17		11.486
24	E	31	202	15.347
	L	5		2.475
25	E	2	150	1.333
	L	2		1.333
26	E	1	150	0.667
	L	0		0.000
27	E	1	250	0.400
	L	0		0.000
28	E	1	200	0.500
	L	2		1.000
29	E	0	256	0.000
	L	0		0.000
30	E	0	200	0.000
	L	0		0.000
31	E	0	200	0.000
	L	0		0.000

Table 4.1-2. Temporal distribution of eggs and larvae entrained at Northfield Mountain Project during 2016 study period

Lifestage	Start Hour	Organism Count	Sample Volume (m^3)	Density (#/100 m^3)
Egg	23:00	0	55	0.00
	0:00	1	451	0.22
	1:00	8	401	2.00
	2:00	10	450	2.22
	3:00	8	402	1.99
	4:00	11	500	2.20
	5:00	18	98	18.37
Larvae	23:00	0	55	0.00
	0:00	0	451	0.00
	1:00	1	401	0.25
	2:00	12	450	2.67
	3:00	4	402	1.00
	4:00	8	500	1.60
	5:00	3	98	3.06

Table 4.2-1. 2016 Weekly Densities of American Shad Ichthyoplankton Observed in Verification (Offshore) Samples

Week No.	Lifestage	Count	Sample Volume (m^3)	Density (No./100 m^3)
20	E	0	338	0.000
	L	0		0.000
21	E	1	468	0.214
	L	0		0.000
23	E	0	306	0.000
	L	0		0.000
24	E	0	322	0.000
	L	1		0.311
25	E	0	365	0.000
	L	40		10.959
26	E	0	445	0.000
	L	0		0.000
27	E	0	485	0.000
	L	0		0.000
28	E	0	344	0.000
	L	0		0.000
29	E	0	381	0.000
	L	0		0.000
30	E	0	353	0.000
	L	0		0.000
31	E	0	326	0.000
	L	0		0.000

Table 4.3-1. Weekly Mean Count and Variance by Sample Type, Week and Lifestage for Ichthyoplankton Data Collected at Northfield Mountain Project

Sample Type	Week No.	Lifestage	Mean Count ($\bar{x}$)	Variance	n
Entrainment	20	E	0.00	0.00	3
Entrainment	21	E	0.00	0.00	4
Entrainment	22	E	0.00	0.00	5
Entrainment	23	E	6.67	9.33	3
Entrainment	24	E	7.75	20.92	4
Entrainment	25	E	0.67	0.33	3
Entrainment	26	E	0.33	0.33	3
Entrainment	27	E	0.20	0.20	5
Entrainment	28	E	0.25	0.25	4
Entrainment	29	E	0.00	0.00	5
Entrainment	30	E	0.00	0.00	4
Entrainment	31	E	0.00	0.00	4
Entrainment	20	L	0.00	0.00	3
Entrainment	21	L	0.00	0.00	4
Entrainment	22	L	0.40	0.80	5
Entrainment	23	L	5.67	14.33	3
Entrainment	24	L	1.25	0.92	4
Entrainment	25	L	0.67	0.33	3
Entrainment	26	L	0.00	0.00	3
Entrainment	27	L	0.00	0.00	5
Entrainment	28	L	0.50	0.33	4
Entrainment	29	L	0.00	0.00	5
Entrainment	30	L	0.00	0.00	4
Entrainment	31	L	0.00	0.00	4
Offshore	20	E	0.00	0.00	3
Offshore	21	E	0.33	0.33	3
Offshore	23	E	0.00	0.00	3
Offshore	24	E	0.00	0.00	3
Offshore	25	E	0.00	0.00	3
Offshore	26	E	0.00	0.00	3
Offshore	27	E	0.00	0.00	3
Offshore	28	E	0.00	0.00	3
Offshore	29	E	0.00	0.00	3
Offshore	30	E	0.00	0.00	3
Offshore	31	E	0.00	0.00	3
Offshore	20	L	0.00	0.00	3
Offshore	21	L	0.00	0.00	3
Offshore	23	L	0.00	0.00	3
Offshore	24	L	0.33	0.33	3
Offshore	25	L	13.33	277.33	3
Offshore	26	L	0.00	0.00	3
Offshore	27	L	0.00	0.00	3
Offshore	28	L	0.00	0.00	3
Offshore	29	L	0.00	0.00	3
Offshore	30	L	0.00	0.00	3
Offshore	31	L	0.00	0.00	3

Table 4.3-2. Negative Binomial Generalized Linear Model for Count Data for Ichthyoplankton Collected at Northfield Mountain Project. Note the larval entrainment model was not informative prompting fit of a single distribution to describe all entrainment events.

Model	Parameter	Estimate	Std. Error	Z value	p
Entrainment (L)	Intercept	1.999906	2.251958	0.974	0.330
	Week 23	3.083299	2.326116	1.383	0.167
	Week 24	2.571527	2.321933	-0.217	0.828
	Week 25	0.500024	2.648782	-0.690	0.490
	Week 28	0.500024	2.780136	-0.690	0490

Table 4.3-3. Weekly summed extrapolation of eggs and larvae

Week	Pump Volume	Eggs	Larvae
20	28,076,201	0	0
21	27,426,911	0	31,460
22	32,482,856	475,417	607,953
23	32,276,214	3,586,034	2,812,422
24	20,731,612	2,965,183	887,935
25	37,561,327	1,732,921	586,827
26	35,508,448	380,183	122,861
27	35,466,926	252,059	38,168
28	33,978,988	128,776	257,553
29	31,669,228	20,291	40,582
30	45,303,677	0	0

Table 4.4-1. The Equivalent Adult Proportions Based on Shad Returning to Holyoke Dam from 2010 to 2014

Age	Proportion	95% CI
3	0.085	[0.065,0.104]
4	0.398	[0.379,0.418]
5	0.405	[0.385,0.424]
6	0.107	[0.088,0.127]
7	0.005	[0.000,0.025]

Table 4.4-2. The Estimate of Equivalent Juvenile (J) and Adult American Shad Loss Due to Entrainment of Eggs and Larvae at Northfield Mountain Project in 2016

Starting Lifestage	Equivalent Loss by Stage/Age (years)					
	J	3	4	5	6	7
Egg	1,987	69	152	45	2	0
Larvae 4	106	237	70	3	0	0
Total	**2,093**	**306**	**222**	**48**	**2**	**0**

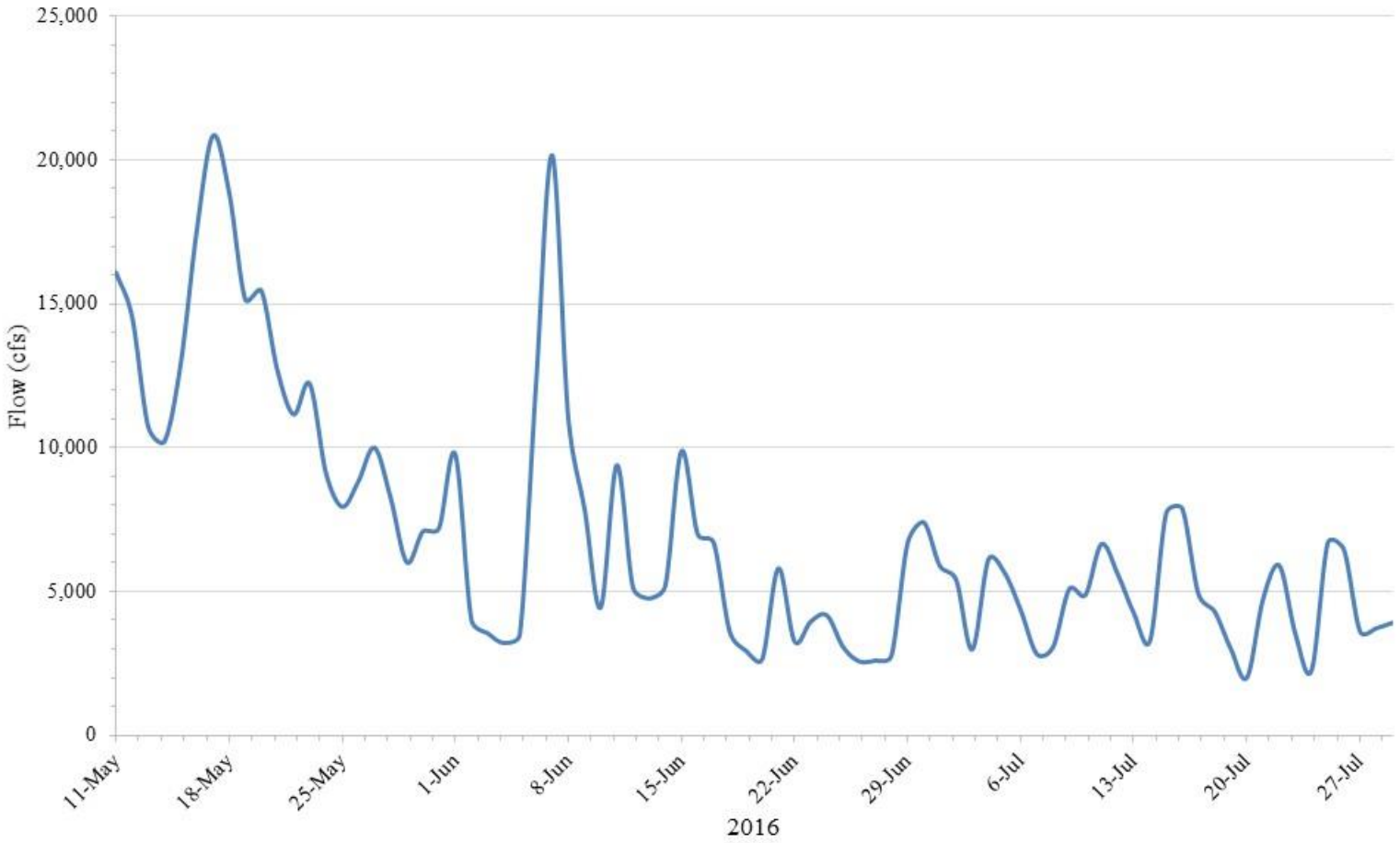


Figure 4.0-1: Connecticut River 15-Minute Flow at the Montague USGS Gage during the Northfield Mountain Project 2016 Ichthyoplankton Study

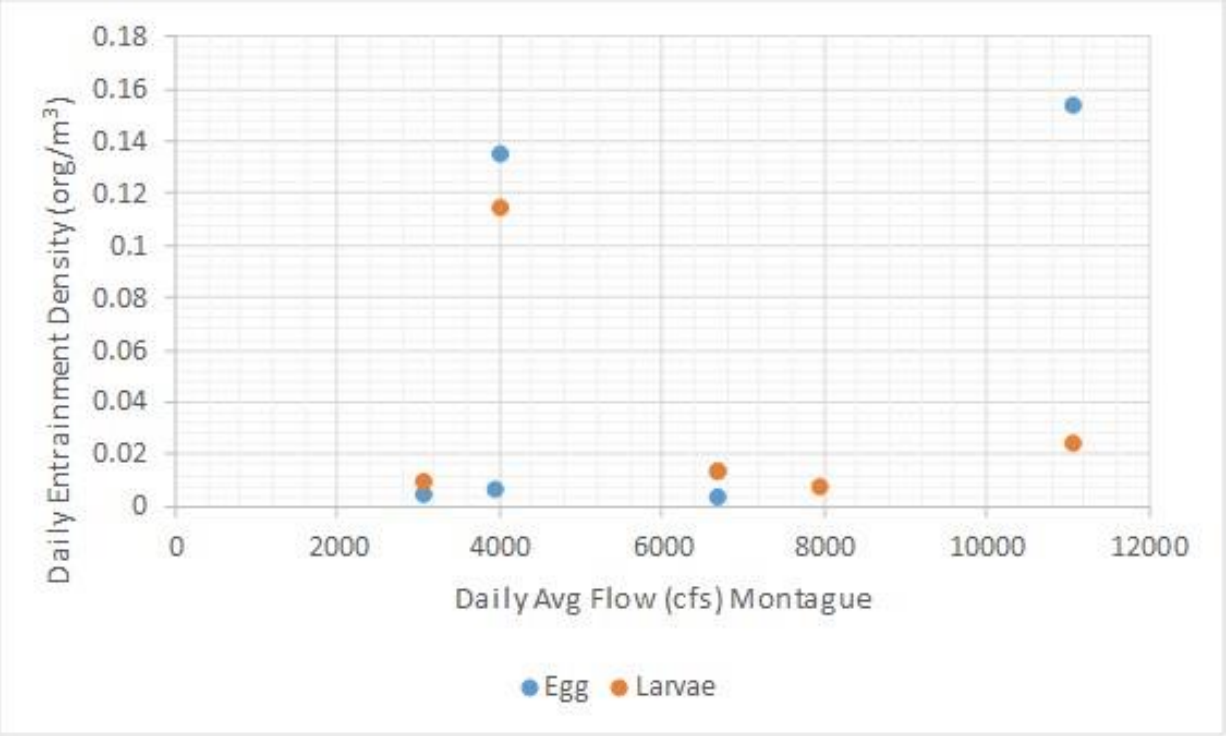


Figure 4.1-1: The 2016 daily entrainment density at Northfield Mountain Project matched with the daily average flow at Montague gage.

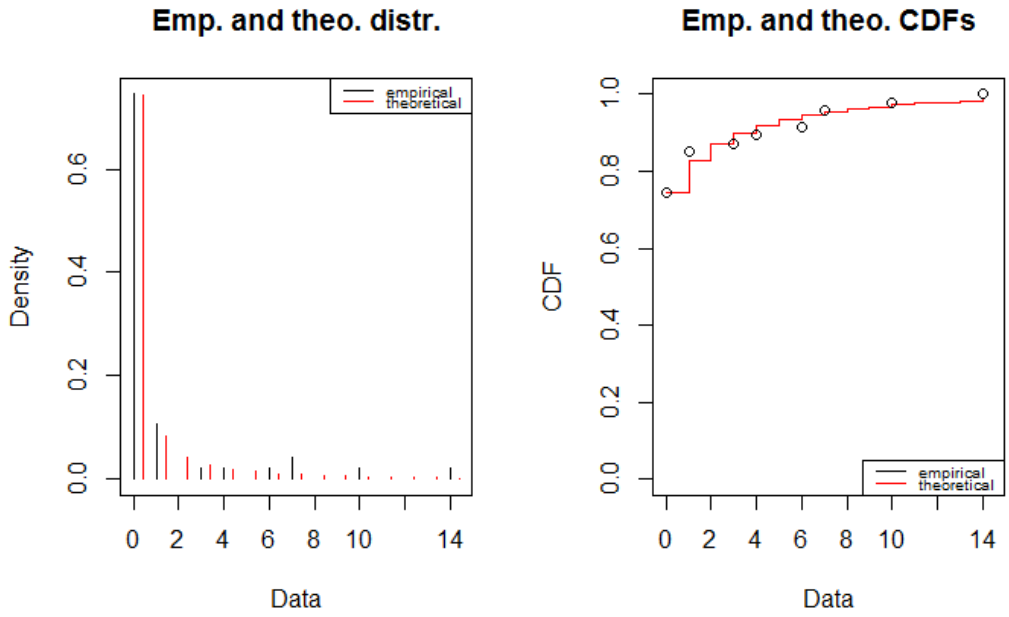


Figure 4.3-1 Negative binomial fit to 2016 data.

Note observed and theoretical counts match up very well. However, the overabundance of zero count samples in 2016 resulted in an uninformative distribution prompting the use of more traditional methods.

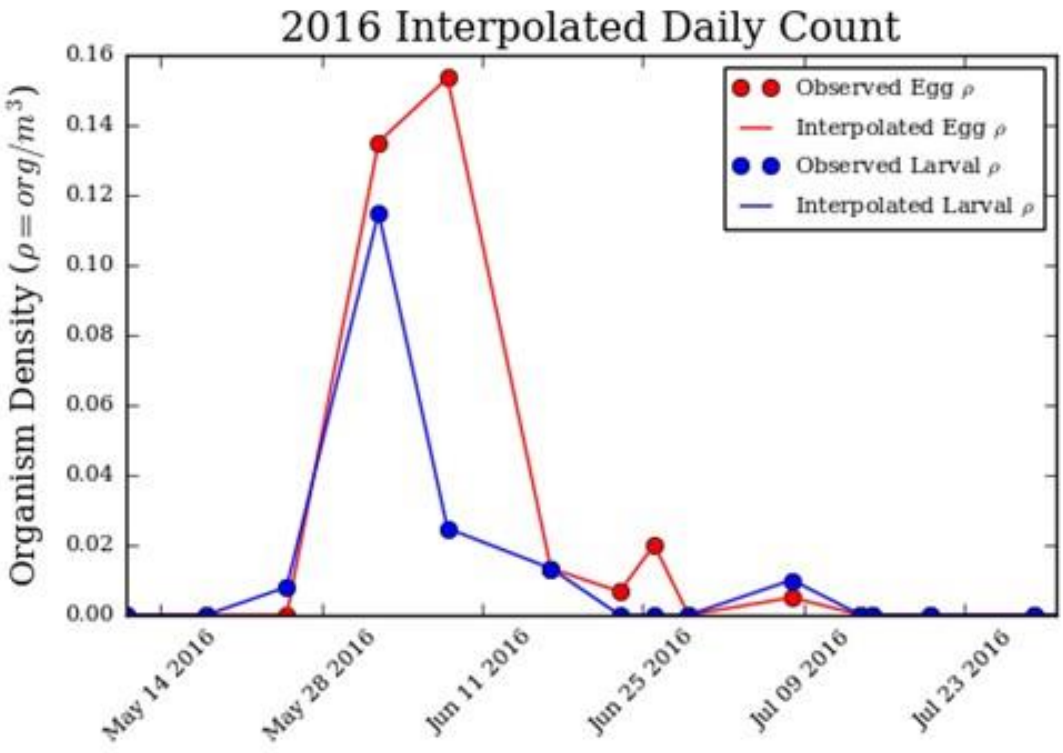
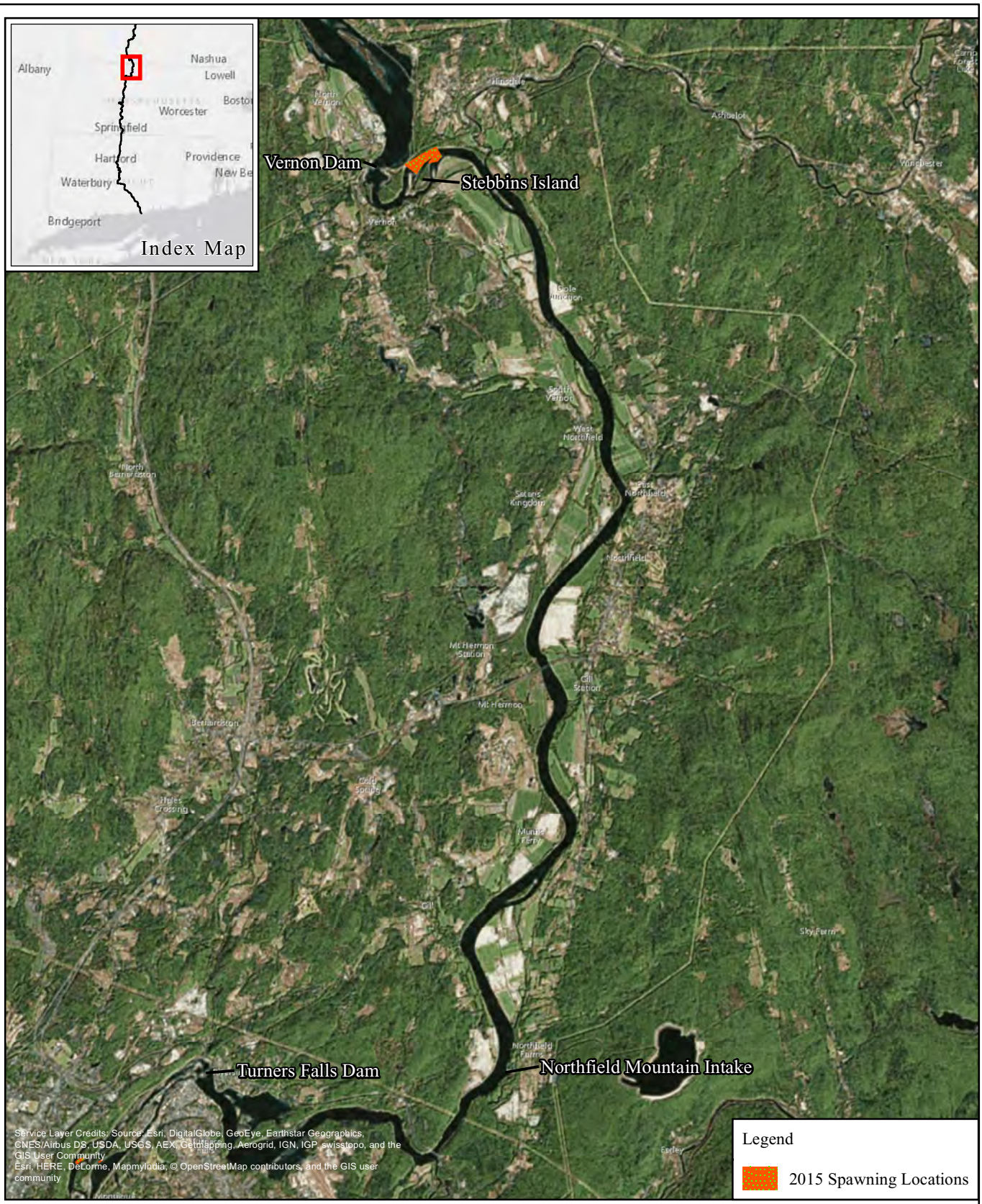


Figure 4.3-2 Interpolated daily sample density (organisms per cubic meter of water) for 2016 data.
Note that the interpolation method reproduces empirical data while providing a linear function between observations.



Northfield Mountain Pumped Storage Project (No. 2485) and Turners Falls Hydroelectric Project (No. 1889)

Ichthyoplankton Entrainment Assessment
at the NorthfieldMountain Project
Relicensing Study 3.3.20

N

0 0.75 1.5 3 Miles

Figure 4.5-1:
Shad Spawning Location
Identified in
Turners Falls Impoundment

Path: W:\gis\studies\3_3_20\Maps\Figure4_5_1.mxd

5 DISCUSSION

In the Connecticut River from mid-May through mid-June, American Shad spawn mostly at night when water temperatures are between 14ºC and 23ºC (Crecco & Savoy, 1987; Marcy, 2004). Water temperature is considered to be the major variable controlling egg development and the timing of spawning (Savoy *et al.*, 2004). Shad eggs hatch in 8 to 12 days at 13-15°C, 6 to 8 days at 17°C, and 3 days at 24°C (Savoy *et al.*, 2004). Newly hatched shad larvae (7-10 mm total length (TL)) occur during May and June and remain near the river bottom until the yolk sac is nearly absorbed about 3 to 4 days later (Savoy *et al.*, 2004). Subsequent to yolk absorption, shad larvae (10-12 mm TL) are transported by river currents into eddies and backwater areas where current velocities are relatively low (Crecco *et al.*, 1983).

A study to determine locations of shad spawning was conducted in 2015. Results indicated that shad spawn just downstream of Vernon Dam near Stebbins Island well upstream of the Northfield Mountain Project intake/tailrace. Densities of shad eggs and larvae at the upriver spawning site were higher than those found at the Northfield Mountain Project in 2015. Lower shad ichthyoplankton densities at the Northfield Mountain Project may be explained by the location of the actual spawning area far upstream of the Northfield intake in the TFI. Researchers have reported that fertilized shad eggs roll along the bottom for 1.6-6.4 km (Savoy *et al.*, 2004).

2016

While the shad ichthyoplankton densities in samples collected at the Northfield Mountain Project were low, when extrapolated by the volume of water pumped at night during the spawning season, approximately 9.5 million shad eggs and 5.4 million shad larvae were estimated to be entrained at the Northfield Mountain Project in 2016. However, to put these numbers in perspective, American Shad spawning strategy includes broadcasting large numbers of eggs which experience high natural mortality. American Shad spawn between 150,000-500,000 eggs per female, and fecundity increases with age, length, and weight (Savoy *et al.*, 2004). Fecundity estimates are higher for broadcast spawners, which do not build protective nests to guard their young from predators. As such, the survival fractions for young produced by broadcast spawners tend to be low.

Since only about 1 out of every 100,000 eggs survives to become a spawning adult, high fecundity is critical for sustaining the stock (Savoy *et al.*, 2004). American Shad eggs in the Connecticut River experienced annual mortality ranging from 24% to 44% per day between 1979 and 1987 (Savoy & Crecco, 1988). As a consequence, between 5% and 19% of the fertilized eggs survive to hatching (Savoy & Crecco, 1988). American Shad larval mortality rates are highest (17-26% per day) among first-feeding larvae, and then decline throughout larval development (Crecco *et al.*, 1983). The larval stage for American Shad lasts between 4 and 6 weeks, during which the larvae grow fairly rapidly (0.4 mm day) to about 22-26 mm TL (Savoy & Crecco, 1988). Based on the 1979-1984 survivorship data, 60-80% of newly hatched larvae die within 3 to 7 days after feeding begins.

The number of equivalent juvenile and adults lost to entrainment at the Northfield Mountain Project was estimated to be 2,093 juvenile shad or 578 adult American Shad for the 2016 spawning season based on the entrainment estimates and published survival fractions discussed above. To put these numbers into perspective, the number of American Shad passed in 2016 at the Turners Falls Gatehouse fishway and the Vernon fishway were 54,069 and 35,807, respectively.

Comparison of 2015 and 2016

In 2015, FirstLight conducted the ichthyoplankton entrainment study from May 28 to June 17 in accordance with the approved study plan. Over the course of the 2015 study, 23 entrainment samples and 12 validation samples were collected, processed and analyzed to estimate of the American Shad eggs and larvae entrained

at the Northfield Mountain Project. The shad ichthyoplankton densities in samples collected in entrainment and offshore at the Northfield Mountain Project were low most likely because shad spawning did not occur in the proximity of the Northfield Mountain Project tailrace. However, when extrapolated by the volume of water pumped during the study period from May 28 to July 17, 2015 just over 3 million shad eggs and 500,000 shad larvae were estimated to be entrained at the Northfield Mountain Project in 2015. Based on the entrainment estimates and published survival fractions, the number of equivalent juvenile and adults lost to entrainment at the Northfield Mountain Project in 2015 was estimated to be 696 juvenile shad or 94 adult American shad.

The higher shad ichthyoplankton densities recorded in 2016 coincided with the highest Connecticut River juvenile index of abundance recorded. Since 1978, the CT DEEP has conducted seine studies to estimate an annual index of juvenile shad abundance in the Connecticut River at a number of sites from Holyoke, MA to Essex, CT between July and October. The annual juvenile index of abundance has shown no trend over time and during the 38 years of sampling the arithmetic mean CPUE averaged 47. The 2015 annual juvenile index of abundance arithmetic mean CPUE was 37.9 which indicated a moderate year class (J. Benway CT DEEP *pers. comm*. 11/2016). In 2016 the arithmetic mean CPUE was 262.3 which was the highest index ever recorded (J. Benway CT DEEP *pers. comm*. 11/2016). The next highest arithmetic mean CPUE was 105.8 in 1994 (J. Benway CT DEEP *pers. comm*. 11/2016). Juvenile indices have been positively correlated with recruitment levels of adult females returning to the Connecticut River 4-6 years later Savoy *et al.*, 2004). The higher entrainment rates at the Northfield Mountain Project in 2016 did not seem to have an effect on the subsequent year class strength of the Connecticut River juvenile shad. June river flow, water temperature, and zooplankton availability have been linked to year class strength (Savoy *et al.*, 2004). Dominant year-class strength of shad is most likely to occur when lower than normal June flows are coupled with moderate spawning stocks (Savoy *et al.*, 2004).

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